LOT DRAINAGE CHARACTERISTICS STUDY
CLAY TILL SOILS

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LOT DRAINAGE CHARACTERISTICS STUDY
CLAY TILL SOILS

June 1992

Prepared by:

CH2M Hill Engineering Ltd.

The views and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as expressing the opinions of Alberta Municipal Affairs.

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FOREWORD

The project documented in this report received funding under the Innovative Housing Grants Program of Alberta Municipal Affairs. The Innovative Housing Grants Program is intended to encourage and assist housing research and development which will reduce housing costs, improve the quality and performance of dwelling units and subdivisions, or increase the long term viability and competitiveness of Alberta's housing industry.

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As the type of project and level of resources vary from applicant to applicant, the resulting documents are also varied. Comments and suggestions on this report are welcome. Please send comments or requests for further information to:

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EXECUTIVE SUMMARY

Foundation drain systems around residential basements contribute significant flow into the sanitary sewers to which they are connected. This flow can, and frequently does cause sewer overloading, surcharging, and basement flooding. Where foundation drains are connected to combined sewers, the resulting flows can increase the frequency and duration of combined sewer overflows. There are extra capital and operating costs of the collection and treatment facilities resulting from the increased flow.

This project determined to what extent different lot drainage characteristics affect foundation drain flow in clay till soils. From previous research, the factors that affected foundation drain flow were lot grading, backfill practice, ground covers, and roof leader discharge locations. To vary these conditions at private residences was considered impractical, and in the fall of 1990 a test facility was constructed in Strathcona County. The facility allowed the effects of these factors to be closely monitored. The facility's foundation drains, sump pump installations and site instrumentation were designed to carry out lot drainage characteristics testing.

The testing procedure used to assess the effects of the various lot drainage characteristics was:

- Apply a design rainstorm to the test facility
- Measure the foundation drain response to the rainstorm
- Measure the groundwater table response.

The tests were repeated for the various lot drainage characteristics discussed above. Data for each test were recorded and the results analyzed and compared for the various lot drainage characteristics.

Based on the research conducted at the test facility, it was concluded that the following lot characteristics significantly impact foundation drain response for clay till soil:

- Compaction of the backfill zone - foundation drain response for compacted clay till was one-tenth that of uncompacted
- Grading of the backfill zone - providing positive drainage away from the foundation reduced drain flow by one-half

- Location of the roof leaders - proper roof leader practices reduced foundation drain flow by one-third.

These factors are not multiplicative and the comparisons were derived when the parameter under consideration was varied while all other lot parameters were held constant.

The test program produced a wide range of responses in foundation drain flows. Two extreme cases are noted here. A well graded lot with proper lot drainage practice produced 0.01 L/s of foundation drain flow. In comparison, the foundation drain response for uncompacted backfill with poor lot drainage practices was 0.90 L/s for the same storm event.

The following recommendations for lot drainage characteristics reflect the findings of the project:

- Compaction of the backfill material for new homes should be specified
- Saturated and/or frozen materials should not be used as backfill
- Grading of the backfill zone should be a minimum of 5 percent away from the foundation
- Roof leaders should have an attached 1.5 m extension
- Foundation drain flow values vary from lot to lot, and subdivision to subdivision. However, the following design values are recommended:
    - 0.08 L/s/house for older subdivisions with settled backfill zones and a variety of lot characteristics
    - 1.3 L/s/house for new subdivisions with uncompacted backfill and a majority of the homes not landscaped or under construction
- Further evaluation of engineered backfill should be undertaken
- No changes should be made to the present practice of covering drain tile with 150-mm of crushed stone
- Foundation drain flow should be discharged to the surface, using sump pump systems.

GLOSSARY OF TERMS

SOURCE: 1) Handbook of Steel Drainage and Highway Construction Products (Canadian Edition) American Iron and Steel Institute
2) Manufacturer's Literature

Backfill:	Earth or other material used to replace material removed during construction.
Backfill Compaction:	Percent compaction (density) for backfill (required or expected).
Block Rainstorm:	A synthetic design storm with uniform intensity that is the average intensity of the Chicago method.
Compaction:	The densification of a soil by means of mechanical manipulation.
Data Logger:	A stand alone electronic storage device that records information on an assigned time interval.
Design Frequency:	The recurrence interval for hydrologic events used for design purposes. As an example a design frequency of 50 years means a storm of a magnitude that would be expected to recur on the average of once in every 50 years.
Design Storm:	A precipitation event that, statistically, has a specified probability of occurring in any given year (expressed either in years or as a percentage).
Discharge:	The actual volume of water flowing from a drainage structure per unit of time.
Download:	A complete memory transfer of all the data loggers memory to a disk file (computer) for diagnostic purposes.
Drainage:	Interception and removal of ground water or surface water by, artificial or natural means.
Engineered Soil:	A selected soil of known properties placed in a prescribed manner.
Foundation:	That portion of a structure (usually below the surface of the ground) which distributes the pressure to the soil. Footing has similar meaning.
Foundation Drain:	A perforated pipe which collects ground water from the foundation or footings for the purpose of draining unwanted waters away from such structures.

Grade:	Refers to slope, or ratio of fall of rise or fall of the grade line to its length.
Ground Water Table (Level):	Upper surface of the zone of saturation in permeable soil.
Head:	The height of water (energy) above any plane or point of reference.
Hydrograph:	A graph of runoff rate, inflow rate, or discharge rate, versus time.
Hyetograph:	A graph showing average rainfall, rainfall intensities, or rainfall volume over specified areas, with respect to time.
Icing:	The gradual accumulation of ice resulting from freezing water over a period of weeks or months.
Impervious:	Impenetrable. Completely resisting entrance of liquids.
Infiltration:	The passage of water into the soil. The term is also used to refer to groundwater entering a sewer system through joints, manholes, etc. infiltration is not usually desirable in sanitary sewer systems, but may be desirable in urban storm drain systems to control groundwater table, and protect roadway pavements.
Inflow:	The water discharged into a sewer system from all possible sources but not infiltration.
Permeability:	A property of soils which permits free passage of any fluid. Permeability depends on grain size, void ratio, shape and arrangement of pores.
Return Period:	The average period in years between occurrences of a discharge equalling or exceeding a given value.
Roof Leader:	A drain or pipe that conducts storm water from the roof of a structure downward and into a sewer for removal from the property, or onto or into the ground for seepage disposal.
Surcharge:	The flow condition occurring in closed conduits when the hydraulic grade line is above the crown of the sewer.
Trapezoidal Rainstorm:	A simulated rainstorm for which the intensity is varied over the duration of the simulation to represent the intensity that occurs during the natural event. The plot of intensity versus duration, of the event being simulated, resembles the shape of a trapezoid.

1.0 INTRODUCTION

1.1 Objectives

Foundation drain systems around residential basements contribute significant flow into the sanitary or combined sewers to which they are connected. This flow can, and frequently does, result in:

- Sewer overloading, surcharging and basement flooding
- Increase in the frequency and duration of combined sewer overflows
- Extra capital and operating costs for collection and treatment facilities.

The objectives of this project were to determine to what extent different construction and lot drainage characteristics affect foundation drain flow and to recommend general improvements to design and construction practices to reduce these flows for lots that have clay till soil as a backfill material. In support of these objectives, the effects of various lot characteristics on foundation drain flow were measured and analyzed.

Several factors including lot grading, backfill practice, ground cover, and roof leader locations affect the magnitude of foundation drain flow. Due to the inability to vary these factors at private homes, the Strathcona Research Facility was built with funding from Alberta Municipal Affairs, the City of Edmonton, Strathcona County, and the New Home Warranty Program of Alberta. The facility, which is described in detail in Appendix A, was designed to accommodate lot drainage research.

1.2 Project Scope

This project was the first in a series of four projects which will, by the end of 1992, comprise the overall Lot Drainage Characteristics Study. The projects will determine the extent to which different lot characteristics affect foundation drain flows. Various aspects of the projects are illustrated by Figure 1. The findings will be used to determine design flow rates and identify possible improvements in construction methods and design standards to reduce foundation drain flows. The research findings may form the basis for new requirements in the Building Code. The research may also lead to recommendations that could reduce the costs of sewerage collection systems and wastewater treatment facilities, and reduce the risk of basement flooding caused by sewer backup. A brief description of the four projects (Figure 1) follows.

Project 1 - Clay Till Soils The focus of this project was to establish benchmark correlations for certain parameters and to determine foundation drain response for clay till soils.

Project 2 - Lot Drainage Characteristics for Sandy Soils Incorporating the benchmark information from Project 1, testing was carried out on sandy soil backfill, repeating the same combinations of lot characteristics as in the clay till project. Accordingly, the soil type (permeability) was the varied lot characteristic. For sandy soils, uncompacted backfill was not tested since after initial water flushing the backfill was considered consolidated. Approximately twenty sets of data were gathered.

Lot Drainage Characteristic Study

Lot Characteristics	Project 1 Clay Till	Project 2 Sandy Soil	Project 3 Silty Soil	Project 4 Natural Storm Events
Storm Event	4 hr/5 yr 4 hr/50 yr 24 hr/5 yr 24 hr/25 yr	4 hr/5 yr 24 hr/5 yr	4 hr/5 yr 24 hr/5 yr	Natural Rainfall
Lot Configuration	Single Split	Single	Single	Single
Ground Cover	Bare Sod Typical	Bare Sod	Bare Sod	
Compaction of Backfill Zone	Compacted Uncompacted Engineered	Compacted	Compacted Uncompacted	
Grading of Backfill Zone	Good Poor Flat	Good Poor Flat	Good Poor Flat	
Roof Leader	1.5m Extension No Extension Storm Connection	1.5m Extension No Extension Storm Connection	1.5m Extension No Extension Storm Connection	
Measured Data Sets	70	24	30	

Figure 1 Lot Drainage Characteristics Study

Project 3 - Lot Drainage Characteristics for Silty Soils Testing similar to Projects 1 and 2 will be carried out on a silty soil backfill, again varying the soil type and testing the same lot characteristics, including the compacted and uncompacted conditions. Approximately thirty sets of data are planned.

Project 4 - Evaluation of Natural Storm Events Throughout the study, foundation drain response to natural storms will be monitored to provide additional data to complement the simulated storm tests. The data will represent approximately a 3-year record of foundation drain responses to natural storm events and possibly winter (rain) storm and snowmelt events. The objective of Project 4 is to analyze and correlate the natural event information to the simulated storm findings in the previous studies and combine all study findings into a comprehensive report/design manual.

1.3 Description of Research Method

The research method used for the project was that of an experimental study, where characteristics such as compaction, grading and roof leader practices were independent variables and foundation drain response was the dependent variable. Projects 2 and 3 varied soil type, or permeability, of the backfill zone. The test facility was designed to allow one independent variable to be changed while keeping the other factors constant and measuring the resulting foundation drain response.

The project work included:

- Preparation of a workplan that provided flexibility and coordination for concurrent foundation wall research being carried out by the University of Alberta

- Preparation of the research facility for the testing of lot drainage characteristics
- Design of onsite monitoring requirements and equipment acquisition, installation, and calibration
- Field testing and data collection for the simulated rainfall events
- Analysis and evaluation of the testing program results and formulation of recommendations.

1.4 Literature Review

An extensive review of books, articles, and reports was conducted. Several municipalities and agencies have investigated Infiltration/Inflow (I/I) to which foundation drain flow is a contributor. Several reports are reviewed in detail in Appendix D.

Magnitudes of foundation drain contributions resulting from rainfall events have not been accurately determined; however, several studies have shown that resulting flowrates cause surcharging in sewers. In 1989 the study, Field Evaluation of Foundation Drain Response, monitored five residential lots in Edmonton. Soil type, backfill practices, grading, ground cover, antecedent soil moisture condition and roof leader locations were identified as lot characteristics that may affect foundation drain flow. Detailed testing and manipulation of lot characteristics was not possible because the lots were privately owned and occupied. It was concluded that controlled testing was necessary to quantify foundation drain flow as a function of each lot characteristic.

Previous (I/I) studies have also identified foundation drain flows as a significant component of total flowrates. Studies carried out in Winnipeg in 1972 concluded that:

1. Foundation flowrates varied from a trickle to 0.45 L/s.

2. Thirty percent (30%) of the rainfall that falls on a house and its backfill zone enters the foundation drain.
3. Homes with proper lot grading had only twenty-five percent (25%) of the flowrate of a home with poor lot grading.

An Ontario study measured the following drain flowrates:

1. The maximum hourly flowrate was measured at 0.544 L/s (1 960 L/h).
2. A maximum daily flowrate of 0.157 L/s (13 600 L/d) was recorded.

The Milwaukee Metropolitan Sewerage Division (MMSD) carried out an analysis of extraneous flows into sanitary sewers and the results regarding foundation flowrates were:

1. The maximum daily flowrate was 0.064 L/s (5 530 L/d).
2. The average maximum hourly flowrate was 0.19 L/s (680 L/h).

The MMSD Private Property I/I study notes that 60 percent of I/I is due to foundation drains and sewer laterals. It also states that the installation of a sump pump with related foundation drain repairs will remove 75 percent of I/I from houses with clayey type soil. Foundation drain flows from residences with elevated or terraced lots are typically lower than from other sites.

Studies done in Winnipeg in 1972 and 1973 showed that most I/I in foundation drains was from roof leader discharges. In situations where poor grading and roof leader discharge practices occur, it is estimated that 95 percent of foundation drain flow is attributable to roof flows.

The study carried out in Edmonton during the summer of 1989 measured the response of foundation drain flow to simulated rainfall events. The results of the study confirmed the significance of foundation drain contributions to sanitary sewer systems. The conclusions were summarized as follows:

- Foundation drains can be a major contributor to storm-related flows in sanitary sewers.
- Design flow allowances are needed in sewer systems if foundation drain connections are to be permitted.
- Foundation drain flows in response to a 50-year return storm vary from 0.07 L/s to 0.49 L/s, significantly higher than design allowances used by some municipalities.
- Roof leader flows are the most significant contributors to foundation drain flows, emphasizing the need for proper roof leader discharge practice, and proper lot grading to direct flows away from the home.

These studies show that foundation drain flows impact sewer systems and where systems are overtaxed, needed capacity could be gained by reducing drain flows.

1.5 Organization of the Document

This report is divided into three ensuing sections:

1. Section 2.0 describes the research facility and the testing procedures used for the work of this project.
2. Section 3.0 summarizes and provides an analysis of the test results for the various lot conditions.
3. Section 4.0 presents the conclusions and recommendations.

Figures and photographs are presented immediately after the text page in which they are referenced. The terminology used in the titles for some figures is based on the condition of the backfill zone. For example, "compacted good" refers to the site condition of compacted backfill with good grading around the foundation.

The technical appendices of the report provide an extensive account of the testing. The appendices provide details, procedures, test results, and geotechnical information. The detailed information in the appendices is summarized in the report and examples of data are presented. Representative tests are included in Appendix B to illustrate and explain various aspects of the data collection and analysis process. The four appendices provide the following information:

- Appendix A describes the site and the design details of the research facility.
- Appendix B presents representative monitored test results.
- Appendix C contains the geotechnical information for the test site and the clay till backfill.
- Appendix D is the literature review.

2.0 SITE DESCRIPTION AND TEST APPROACH

2.1 Test Site Description

The research facility is on the northeast corner of the Strathcona County Reservoir Site, 17th Street and 92nd Avenue, Strathcona County. The site is relatively level with a natural slope of approximately 4.3 percent to the north. It is bounded by gravelled roads on both the south and west sides as shown by Photos 1 and 2. Details of the research facility are presented in Appendix A.

Photo 1. Research Facility Site - The site is being graded to establish a 1.5 percent, back-to-front slope. A flat grade of 1.5 percent was used based on the findings of previous research that suggested the greater the slope of the lot, the lesser the effect of storms on foundation drain response. Also, a lot grade of 1.5 percent is representative of homes that experience foundation drain flows. The photo was taken from the back of the lot looking north.

Photo 2. Site Work Completed - The photograph shows the facility with the site work completed. The photograph was taken from south (back) to north (front).

The foundation drainage system at the site was specially designed for foundation drain research. The facility can be operated as a single site or separated into two zones representing two sites - front-lot and back-lot. To provide this capacity, an impermeable geomembrane (Photo 3), cutoff footings and two sumps with related foundation drain valving, shown in Figure 2, were constructed.

Photo 3. Impermeable Geomembrane - An impermeable geomembrane attached to the cutoff footing and the foundation at diagonal corners of the facility separated (by closing appropriate valves) the subsurface flow of groundwater into back-lot and front-lot inflow.

2.2 Test Approach

2.2.1 Identification of Variables

The research method used for this project was experimental study. This method is used in research where there are several independent variables that may affect an outcome - in this study, the foundation drain response. The effect of each variable is determined by holding all variables constant except the one of current interest. For this project the independent variables were the lot characteristics described below (refer also to Figure 1 in Section 1.2):

1. Drainage pattern; single lot or split lot

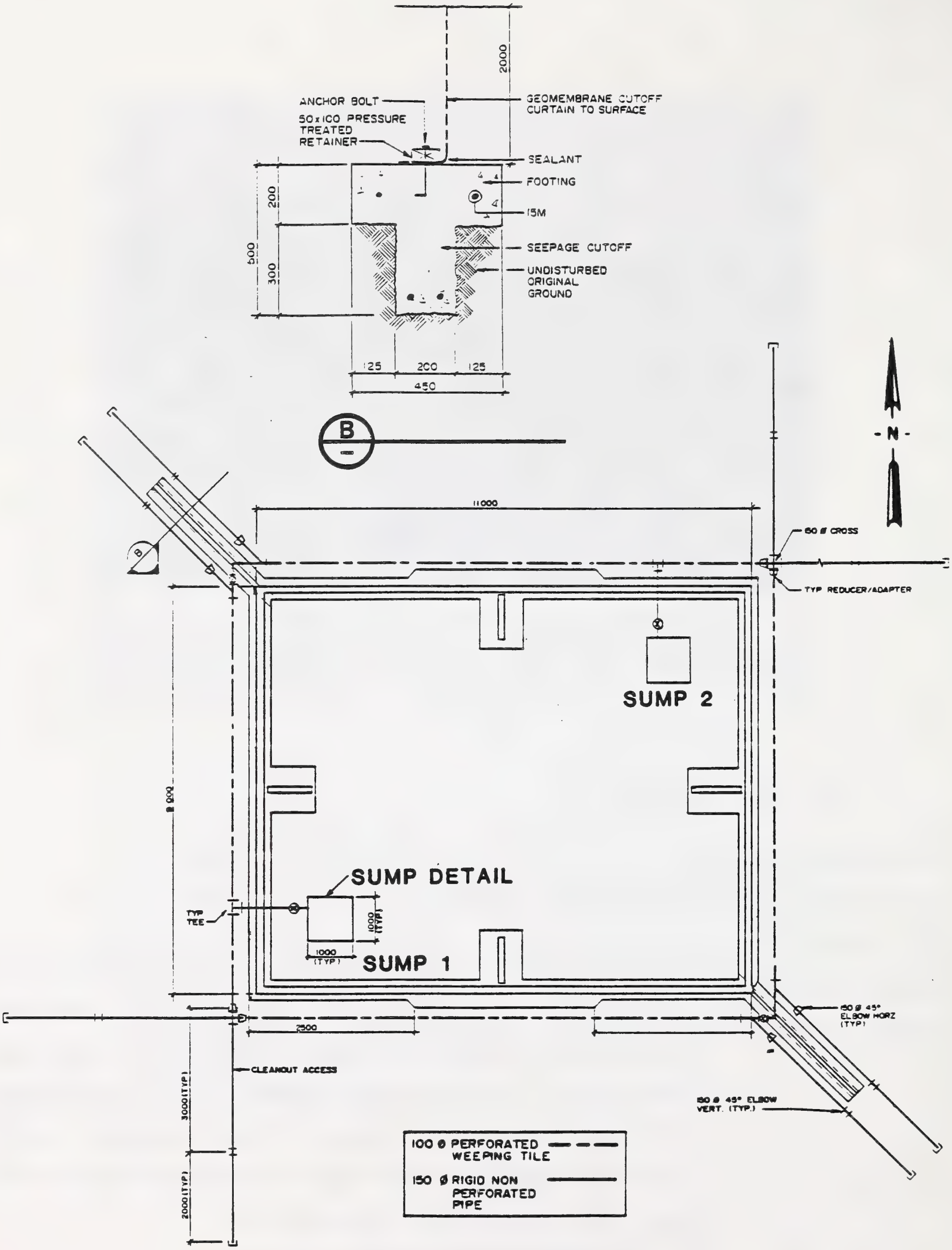

2000
ANCHOR BOLT
50 x 100 PRESSURE TREATED RETAINER
GEOMEMBRANE CUTOFF CURTAIN TO SURFACE
SEALANT
FOOTING
15M
SEEPAGE CUTOFF
UNDISTURBED ORIGINAL GROUND
200
500
300
125
200
125
450
B
- N -
11000
B
150 Ø CROSS
TYP REDUCER/ADAPTER
SUMP 2
8000
SUMP DETAIL
TYP TEE
1000 (TYP)
1000 (TYP)
SUMP 1
2500
150 Ø 45° ELBOW HORZ (TYP)
CLEANOUT ACCESS
3000 (TYP)
2000 (TYP)
150 Ø 45° ELBOW VERT. (TYP.)
100 Ø PERFORATED WEEPING TILE
150 Ø RIGID NON PERFORATED PIPE

Figure 2 FOUNDATION DRAIN AND SUMP PLAN

2. Ground cover conditions around the foundation walls, namely sod, bare earth, and typical cover (a combination of sod, concrete, and flower beds)
3. Backfill conditions within the construction zone:
    - Less than 90 percent of standard proctor density, typifying uncompacted soil
    - 90 percent to 92 percent, typifying moderately compacted soil
    - Engineered backfill (use of an impermeable geotextile membrane within the backfill material)
4. Lot grading conditions adjacent to the foundation wall:
    - Poor (-2 to -5 percent slope)
    - Flat (-2 to +2 percent slope)
    - Good (>5 percent slope)
5. Roof drain discharge locations:
    - At the basement wall
    - At 1.5 meters from the wall
    - Connected directly to the storm sewers
6. Storm Types:
    - Short duration, high intensity - 4-hour duration, 5-year and 50- year return period
    - Long duration, low intensity - 24-hour duration, 5-year and 25-year return period
7. Soil moisture conditions:
    - "Dry" represents conditions after a period of dry weather; a 3-day period was the standard used in the CH2M HILL Edmonton, 1989 testing program
    - "Wet" represents conditions approximately 1 day after a storm simulation

By varying one of the above lot characteristics (independent variable) per test, its affect on foundation drain response (the dependent variable) was determined.

2.2.2 Testing Program

The testing program was conducted in two phases. Phase I consisted of scheduling, preliminary calculations, and site preparation. Phase II comprised actual field testing.

2.2.2.1 Phase 1 - Scheduling, Preliminary Calculations and Equipment Setup

Test Program Schedule

The testing sequence was designed to minimize the number of site changes and the time required. The initial schedule for the testing as proposed in February 1991 is shown by Figure 3. The testing regime was later revised, as shown by Figure 11, to meet the testing constraints determined during the benchmark testing phase (benchmark testing is discussed in Section 2.2.2.2).

Preliminary Calculations

For the four storm events selected for simulation in the testing program, design hyetographs had to be developed. This was done by modifying typical hyetographs from the City of Edmonton to meet the limitations of the site equipment. Due to the hydraulic capacity of the manifolds and soaker hoses, the peak intensities of the short duration storms were limited to a maximum of 60 mm/hour, while the required volume of simulated rainfall was retained. The long duration, 24-hour events provided the contrasting challenge. The head losses in the soaker hoses limited the even distribution of rainfall to intensities of

PROJECT SCHEDULE
JOB NO.: EDM23269.A0
FILE: 23269.WK1

TEST DAY	TEST	TEST CONDITION	SITE CHANGES REQUIRED
1 2 MAY 28	Test 1 & 2	*BENCH MARK-SINGLE* 4HR 1:5 Storm Single Sod Compacted Flat 1.5m from wall	EQUIPMENT & MANPOWER -Initial lot grading -Compact backfill -Place sod
3 4 JUNE 7	Test 3 & 4	*BENCH MARK-SINGLE* 4HR 1:50 Storm Single Sod Compacted Flat 1.5m from wall	No assistance required
5 6 7 JUNE 14	Test 5 & 6	*BENCH MARK-SINGLE* 24HR 1:5 Storm Single Sod Compacted Flat 1.5m from wall	No assistance required
8 9 10 JUNE 21	Test 7 & 8	*BENCH MARK-SINGLE* 24HR 1:50 Storm Single Sod Compacted Flat 1.5m from wall	No assistance required
11 12 JUNE 28	Test 9 & 10	*BENCH MARK-SINGLE* Test Storm Typical Compacted Flat 1.5m from wall	MANPOWER -Remove sod; place concrete pads
13 14 JULY 5	Test 11 & 12	*BENCH MARK-SINGLE* Test Storm Bare Compacted Flat 1.5m from wall	MANPOWER -Remove remaining sod and concrete pads
15	Test 13	*SPLIT* Test Storm Sod Uncompacted Poor Storm	EQUIPMENT & MANPOWER -Lot grading -Remove & replace backfill -Place sod
15	Test 14	*SPLIT* Test Storm Sod Uncompacted Poor 1.5m from wall	No assistance required
16	Test 15	*SPLIT* Test Storm Sod Uncompacted Poor At wall	No assistance required
16 JULY 12	Test 16	*SPLIT* Test Storm Sod Uncompacted Flat Storm	EQUIPMENT & MANPOWER -Grading in backfill zone -Remove & replace sod in backfill zone
17	Test 17	*SPLIT* Test Storm Sod Uncompacted Flat 1.5m from wall	No assistance required
17	Test 18	*SPLIT* Test Storm Sod Uncompacted Flat At wall	No assistance required
18	Test 19	*SPLIT* Test Storm Sod Compacted Good Storm	EQUIPMENT & MANPOWER -Grading in backfill zone -Remove & replace sod in backfill zone
18 JULY 19	Test 20	*SPLIT* Test Storm Sod Compacted Good 1.5m from wall	No assistance required
19	Test 21	*SPLIT* Test Storm Sod Compacted Good At wall	No assistance required
20 21 22 JULY 26	Test 22 & 23	*SPLIT* *2-24 HOUR TEST STORMS* Sod Compacted Good 1.5m from wall	No assistance required
23	Test 24	*SPLIT* Test Storm Sod Compacted Flat Storm	EQUIPMENT & MANPOWER -Grading in backfill zone -Remove & replace sod in backfill zone
24 25 AUGUST 2	Test 25 & 26	*SPLIT-BENCH MARK* Test Storm Sod Compacted Flat 1.5m from wall	No assistance required SUBMISSION OF TEST RESULTS AND TECH MEMO FOR REVIEW
26	Test 27	*SPLIT* Test Storm Sod Compacted Flat At wall	No assistance required
27 28 29 AUGUST 9	Test 28 & 29	*SPLIT* *2-24 HOUR TEST STORMS* Sod Compacted Flat 1.5m from wall	No assistance required
30	Test 30 & 31	*SPLIT-BENCH MARK* Test Storm Typical Compacted Flat 1.5m from wall	MANPOWER -Remove sod; place concrete pads
31	Test 32 & 33	*SPLIT-BENCH MARK* Test Storm Bare Compacted Flat 1.5m from wall	MANPOWER -Remove remaining sod and concrete pads
31 AUGUST 16	Test 34	*SPLIT* Test Storm Sod Compacted Poor Storm	MANPOWER -Grade backfill zone -Replace sod
32	Test 35	*SPLIT* Test Storm Sod Compacted Poor 1.5m from wall	No assistance required
32	Test 36	*SPLIT* Test Storm Sod Compacted Poor At wall	No assistance required
33 34 35 AUGUST 23	Test 37 & 38	*SPLIT* *2-24 HOUR TEST STORMS* Sod Compacted Poor 1.5m from wall	No assistance required
36	Test 39 & 40	*SPLIT-BENCH MARK* Test Storm Sod Engineered Good Storm	EQUIPMENT & MANPOWER -Remove & replace backfill -Install geotextiles -Remove & replace sod in backfill zone
36	Test 41	*SPLIT* Test Storm Sod Engineered Good 1.5m from wall	No assistance required
37 AUGUST 30	Test 42	*SPLIT* Test Storm Sod Engineered Good At wall	No assistance required

Figure 3 INITIAL SCHEDULE FOR TESTING

not less than 5 mm/hour. The resulting design hyetographs simulate natural rainfall by providing a gradual rise and fall of intensity in relation to the storm peak; however, because of the minimum intensity dictated by the equipment, the decision was made to apply the water in pulses, while retaining the volume of the 24-hour events. The design flowrate calculations for the simulated storms are presented in Figures 4a and 4b and the resulting hyetographs for the simulated storm events are shown by Figures 5, 6, 7 and 8.

Equipment Setup

The simulation of storm events was accomplished by applying water through soaker hoses for intensities up to 25 mm/hour (Figures 4a and 4b) and using a combination of soaker hoses and oscillating sprinklers for peak intensities of 25 to 60 mm/hour. Roof leader discharge was simulated by direct connection of a hose to the downspout. The volume of water applied to the site was monitored by the two totalizer meters on the hydrant supply line. Figure 9 is a schematic of the rainfall simulation distribution manifolds and metering.

Site conditions were monitored with the following equipment (Figure 10):

- Natural rainfall events were monitored by a Rimco raingauge and a standard raingauge was used to check the calibration of the station.
- Simulated rainfall rates were measured by two totalizing volume flowmeters and six variable area flowmeters.
- Groundwater fluctuations were monitored by 16 piezometers. Six were equipped with a water level recorder device that recorded water levels every 15 min.

PROJECT: FOUNDATION DRAINAGE STUDY 10-Jun-91 09:59 AM
FILE: HYE_SUMM.WK1 AREA: TOTAL= 561.9628
JOB No.: EDM23269.A0 FRONT= 206.58088
BACK= 355.38192

DESIGN STORM HYETOGRAPHS

4 - HOUR

5 - YEAR STORM - FRONT LOT

START	ELAPSE	INTENSITY	DEPTH OF RAINFALL (mm)		TOT FLOW	ROOF FLOW	ACCUM
TIME (min)	TIME (min)	mm/hr	CALCULATED	ACTUAL	(USGPM)	(USGPM)	VOLUME
00:00	60	6.046	4.101	6.046	5.5	1.3	1.25
01:00	30	38.474	20.192	19.237	35	8.4	5.22
01:30	30	6.046	6.788	3.023	5.5	1.3	5.85
02:00	120	5.496	8.133	10.993	5	1.2	8.12
VOLUME(m^3)			8.10				
DIFFERENCE				0.085			

5 - YEAR STORM - BACK LOT

START	ELAPSE	INTENSITY	DEPTH OF RAINFALL (mm)		TOT FLOW	ROOF FLOW	ACCUM
TIME (min)	TIME (min)	mm/hr	CALCULATED	ACTUAL	(USGPM)	(USGPM)	VOLUME
00:00	60	4.473	4.101	4.473	7	1.0	1.59
01:00	30	38.979	20.192	19.489	61	8.5	8.52
01:30	30	12.780	6.788	6.390	20	2.8	10.79
02:00	120	4.473	8.133	8.946	7	1.0	13.97
VOLUME(m^3)			13.94				
DIFFERENCE				0.084			

4 - HOUR

50 - YEAR STORM - FRONT LOT

START	ELAPSE	INTENSITY	DEPTH OF RAINFALL (mm)		TOT FLOW	ROOF FLOW	ACCUM
TIME (min)	TIME (min)	mm/hr	CALCULATED	ACTUAL	(USGPM)	(USGPM)	VOLUME
00:00	60	10.993	9.802	10.993	10	3.0	2.27
01:00	30	67.055	33.656	33.527	61	14.6	9.20
01:30	30	21.985	12.592	10.993	20	4.8	11.47
02:00	120	7.695	14.633	15.390	7	1.7	14.65
VOLUME(m^3)			14.60				
DIFFERENCE				0.219			

50 - YEAR STORM - BACK LOT

START	ELAPSE	INTENSITY	DEPTH OF RAINFALL (mm)		TOT FLOW	ROOF FLOW	ACCUM
TIME (min)	TIME (min)	mm/hr	CALCULATED	ACTUAL	(USGPM)	(USGPM)	VOLUME
00:00	60	16.294	9.802	16.294	25.5	3.6	5.79
01:00	30	47.924	33.656	23.962	75	10.4	14.31
01:30	30	22.365	12.592	11.182	35	4.9	18.28
02:00	120	9.585	14.633	19.170	15	2.1	25.09
VOLUME(m^3)			25.12				
DIFFERENCE				-0.075			

Figure 4a FLOWRATE CALCULATIONS FOR STORM EVENTS

PROJECT:	FOUNDATION DRAINAGE STUDY		10-Jun-91	09:59 AM
FILE:	HYE_SUMM.WK1	AREA:	TOTAL=	561.9628
JOB No.:	EDM23269.A0		FRONT=	206.58088
			BACK=	355.38192

24 - HOUR DESIGN STORM

5 - YEAR STORM - FRONT LOT

START TIME (min)	ELAPSE TIME (hr)	INTENSITY mm/hr	DEPTH OF RAINFALL (mm) CALCULATED	ACTUAL	TOT FLOW (USGPM)	ROOF FLOW (USGPM)	ACCUM VOLUME
03:00	1.5	5.496	14.357	8.244	5	1.2	1.70
06:00	1	5.496		5.496	5	1.2	2.84
08:00	1	5.496	5.447	5.496	5	1.2	3.97
09:00	1	12.642	12.446	12.642	11.5	2.8	6.59
10:00	1	6.596	6.637	6.596	6	1.4	7.95
13:00	2	5.496	23.725	10.993	5	1.2	10.22
16:00	2.5	5.496		13.741	5	1.2	13.06
VOLUME(m^3)			12.93				
DIFFERENCE				-0.596			

5 - YEAR STORM - BACK LOT

START TIME (min)	ELAPSE TIME (hr)	INTENSITY mm/hr	DEPTH OF RAINFALL (mm) CALCULATED	ACTUAL	TOT FLOW (USGPM)	ROOF FLOW (USGPM)	ACCUM VOLUME
03:00	1.5	5.431	14.357	8.147	8.5	1.2	2.90
06:00	1	5.751		5.751	9	1.3	4.94
08:00	1	5.431	5.447	5.431	8.5	1.2	6.87
09:00	1	12.460	12.446	12.460	19.5	2.7	11.30
10:00	1	6.390	6.637	6.390	10	1.4	13.57
13:00	2	5.431	23.725	10.863	8.5	1.2	17.43
16:00	2.5	5.431		13.579	8.5	1.2	22.25
VOLUME(m^3)			22.25				
DIFFERENCE				0.009			

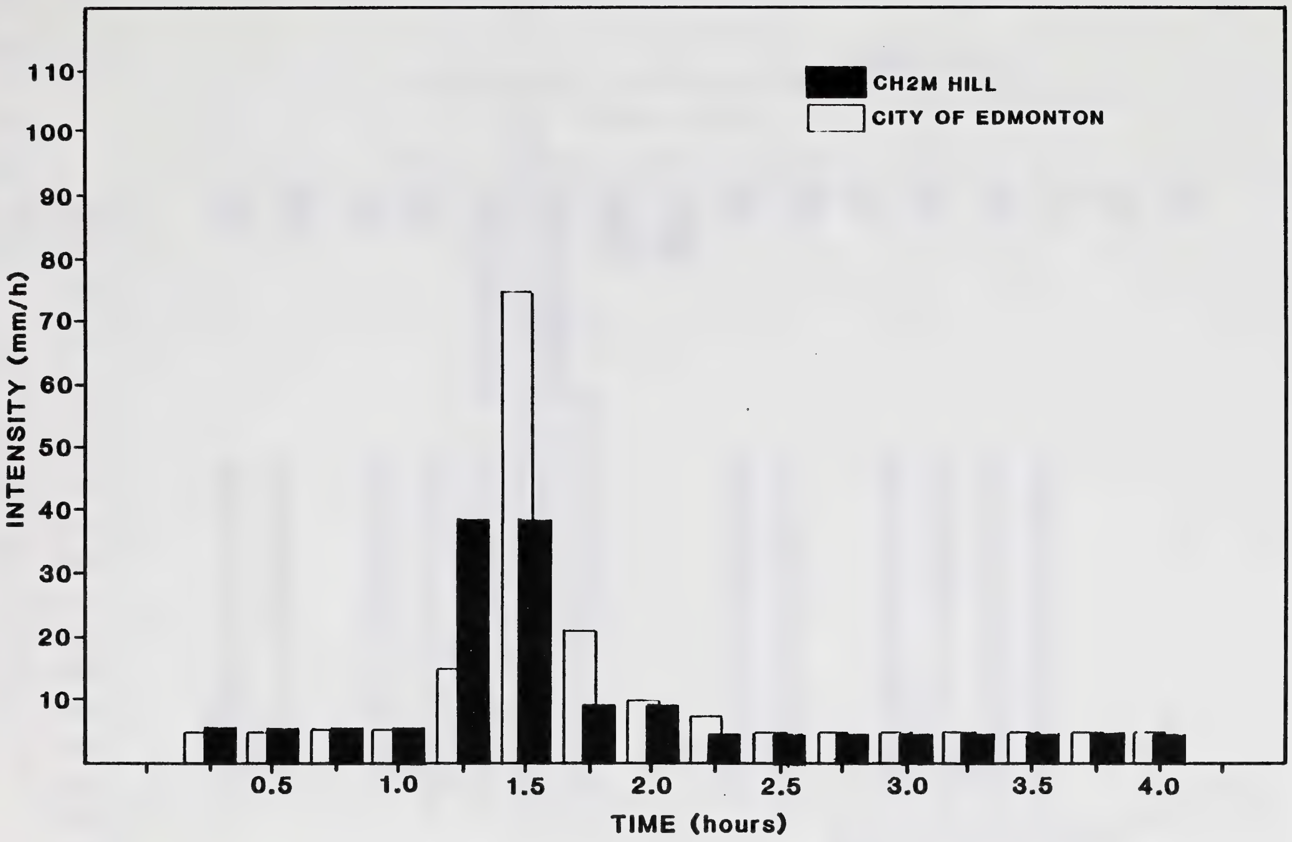
25 - YEAR STORM - FRONT LOT

START TIME (min)	ELAPSE TIME (hr)	INTENSITY mm/hr	DEPTH OF RAINFALL (mm) CALCULATED	ACTUAL	TOT FLOW (USGPM)	ROOF FLOW (USGPM)	ACCUM VOLUME
03:00	2	6.596	21.216	13.191	6	1.4	2.73
06:00	1.5	6.596		9.893	6	1.4	4.77
08:00	1	8.244	8.066	8.244	7.5	1.8	6.47
09:00	1	18.687	18.542	18.687	17	4.1	10.33
10:00	1	9.344	9.827	9.344	8.5	2.0	12.26
13:00	2	6.046	35.059	12.092	5.5	1.3	14.76
16:00	2.5	6.046		15.115	5.5	1.3	17.88
19:00	1	6.046		6.046	5.5	1.3	19.13
VOLUME(m^3)			19.15				
DIFFERENCE				-0.097			

25 - YEAR STORM - BACK LOT

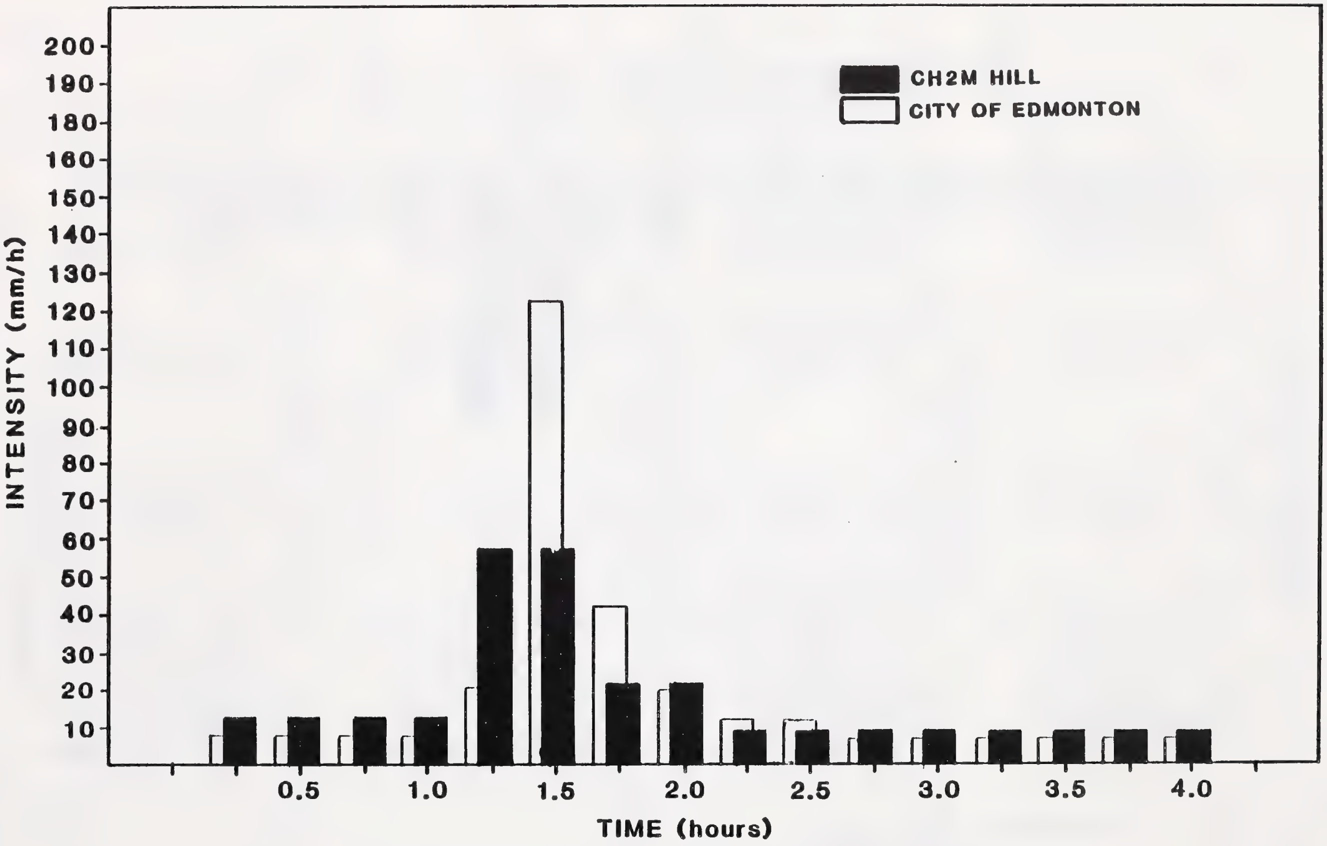
START TIME (min)	ELAPSE TIME (hr)	INTENSITY mm/hr	DEPTH OF RAINFALL (mm) CALCULATED	ACTUAL	TOT FLOW (USGPM)	ROOF FLOW (USGPM)	ACCUM VOLUME
03:00	2	6.070	21.216	12.141	9.5	1.3	4.31
06:00	1.5	6.070		9.106	9.5	1.3	7.55
08:00	1	7.987	8.066	7.987	12.5	1.7	10.39
09:00	1	18.531	18.542	18.531	29	4.0	16.97
10:00	1	9.904	9.827	9.904	15.5	2.2	20.49
13:00	2	6.390	35.059	12.780	10	1.4	25.04
16:00	2.5	6.390		15.975	10	1.4	30.71
19:00	1	6.390		6.390	10	1.4	32.98
VOLUME(m^3)			32.95				
DIFFERENCE				0.104			

Figure 4b FLOWRATE CALCULATIONS FOR STORM EVENTS



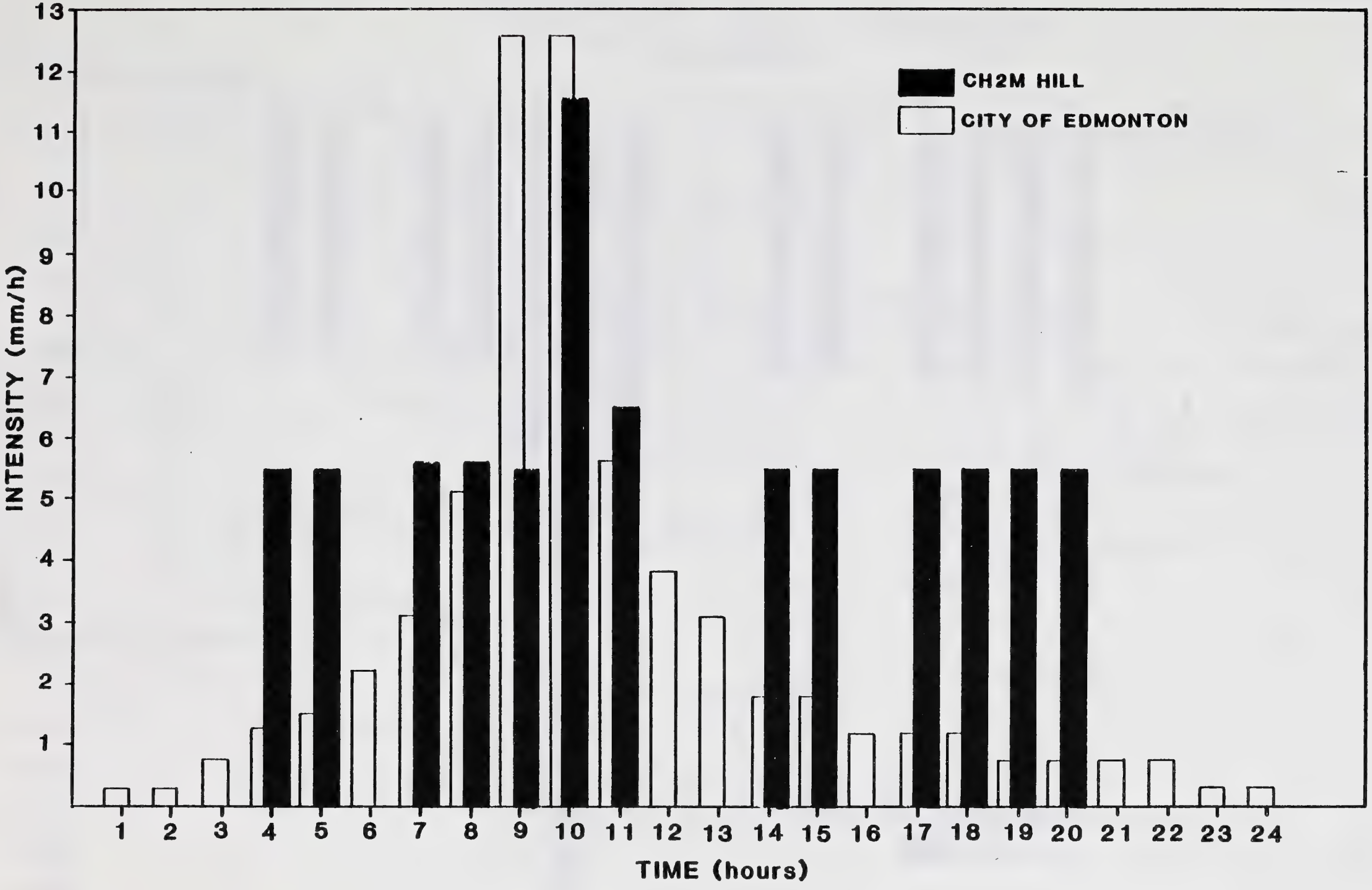
4-HOUR 5-YEAR DESIGN STORM

Figure 5



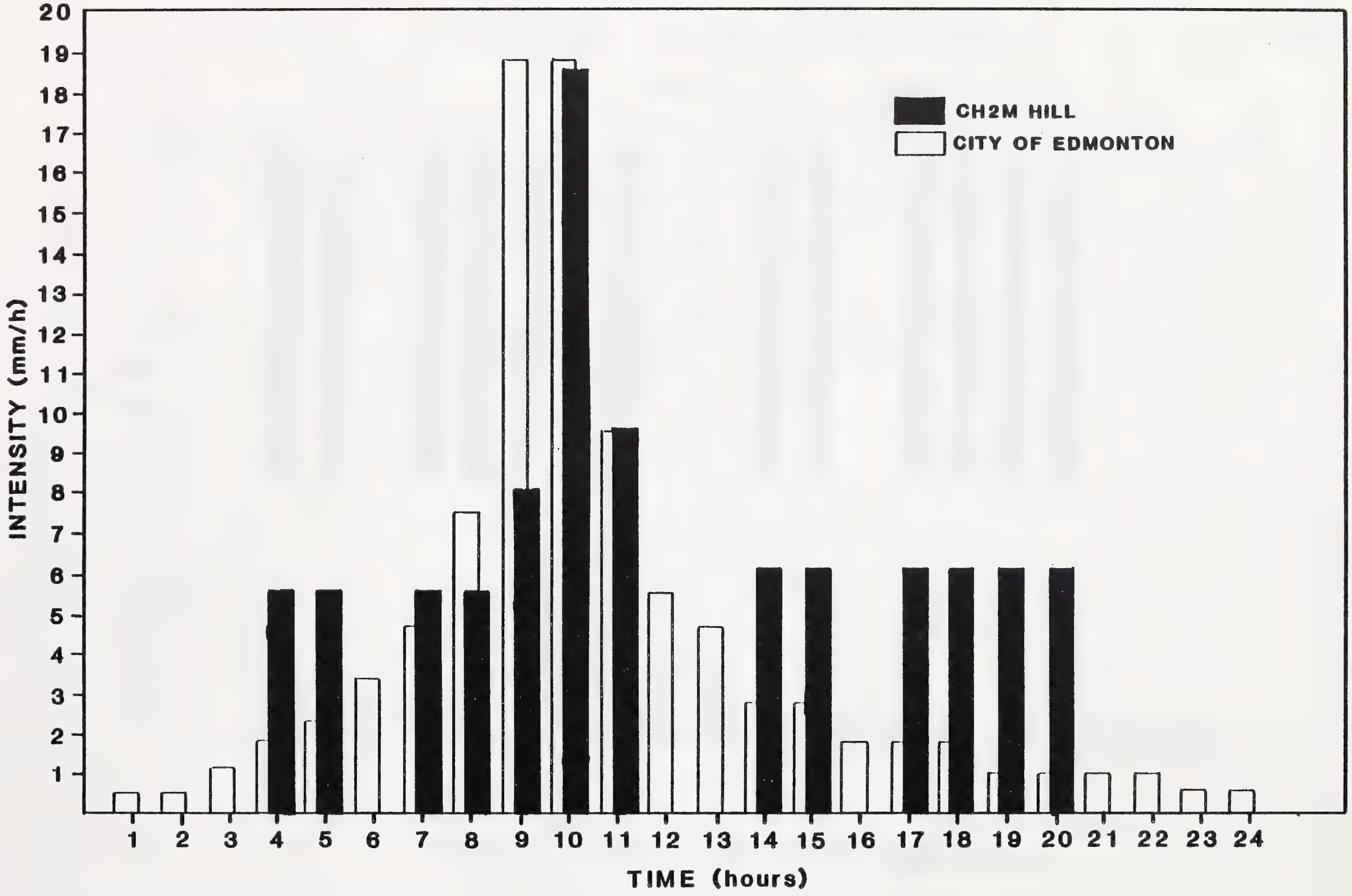
4-HOUR 50-YEAR DESIGN STORM

Figure 6



24-HOUR 5-YEAR DESIGN STORM

Figure 7



24-HOUR 25-YEAR DESIGN STORM

Figure 8

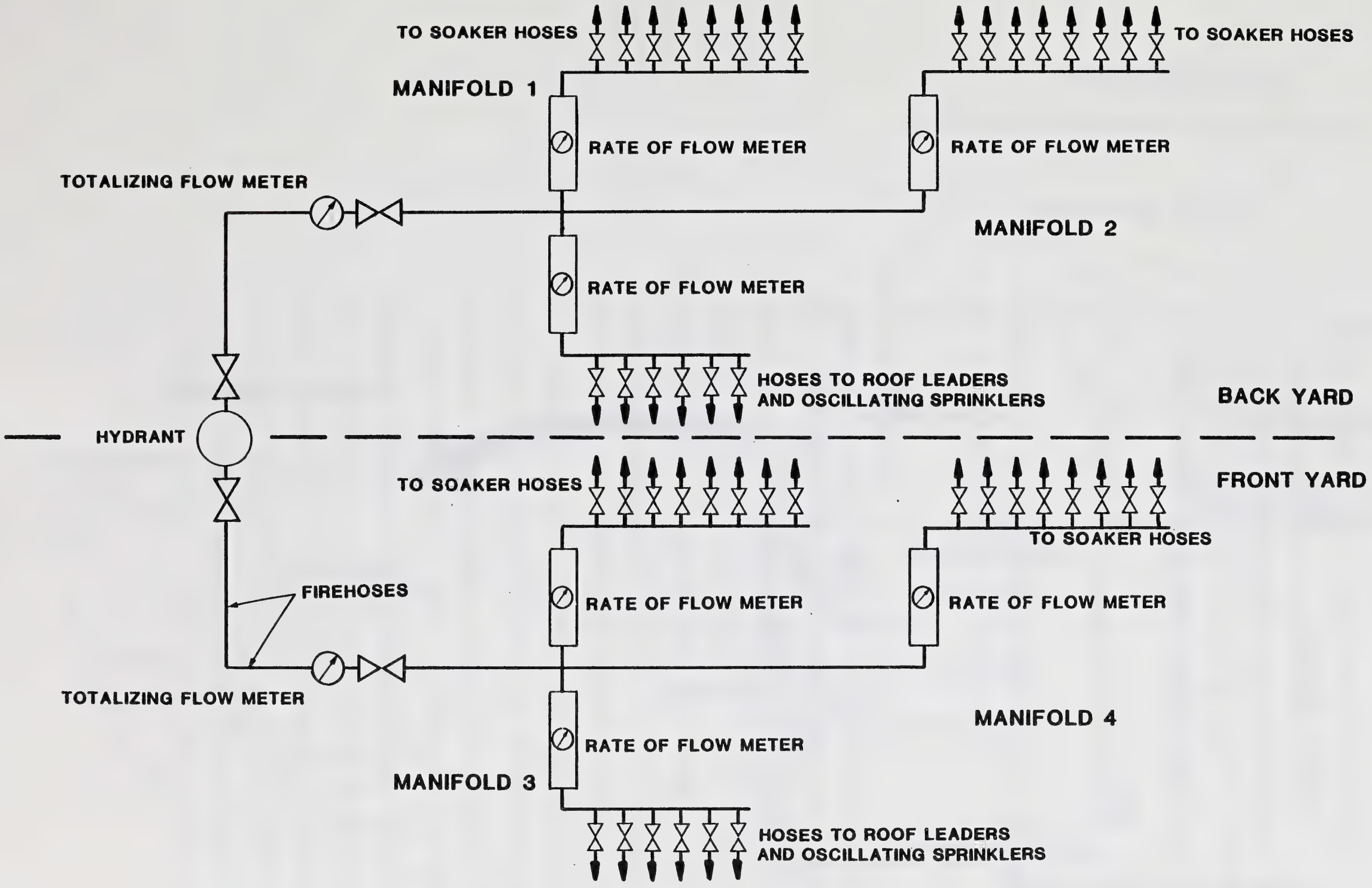


Figure 9 RAINFALL MANIFOLD

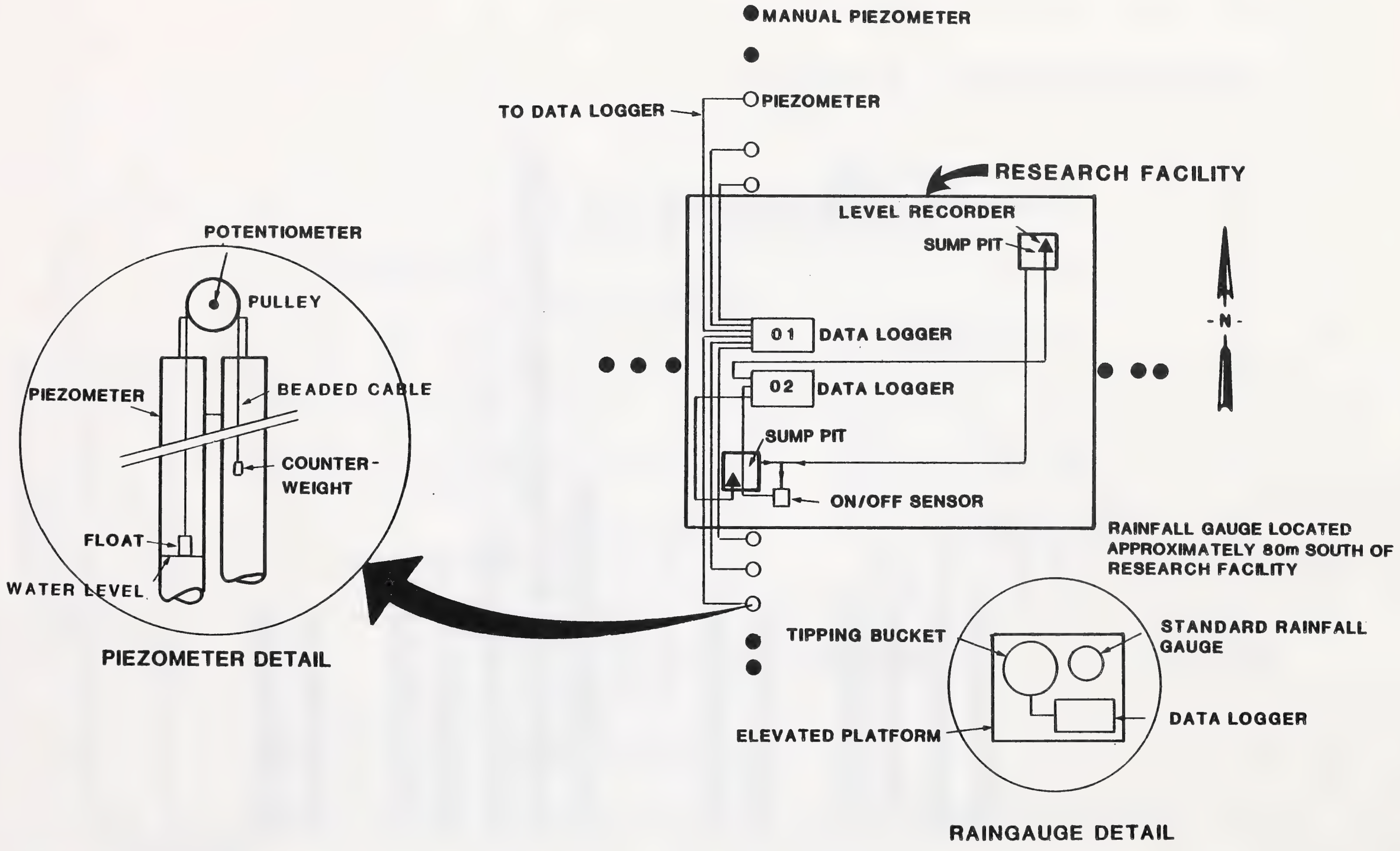


Figure 10 INSTRUMENTATION SCEMATIC SITE

The remainder of the piezometers were manually monitored using a reel type water level recorder.

- Foundation drain responses were measured with water level recorders in the sumps and on/off sensors on the pumps.
- Infiltration rate testing was conducted with two infiltrometers.

2.2.2.2 Phase II - Field Testing Procedure

The field testing component was conducted in two stages: benchmark testing and the remainder of the field testing.

Benchmark Testing

A series of tests were carried out to determine whether definable relationships existed within the variations of selected primary variables such that, from the actual foundation drain response to a particular variation for a given set of conditions, the response to other variations for that same set of conditions could be calculated or predicted. For example, knowing the response to a 4 hour - 5 year return storm event could allow the calculation of the responses to 4 hour - 50 year, 24 hour - 5 year and 24 hour - 25 year storms. For this testing, termed "benchmark testing", the primary variables selected were storm events (4 variations), lot configurations (2 variations) and ground cover type (2 variations - typical and sod). In addition to the potential for providing valuable empirical information, definable relationships within these variable groups could reduce the number of tests required to be done for the balance of this project and for the remaining three projects in the series. Periodically, tests were carried out to confirm the accuracy of benchmark relationships For instance, a 24 hour - 5 year storm was simulated and the foundation drain response was compared to the response predicted by benchmark data.

Benchmark testing was conducted with the following lot characteristics held constant:

1. The backfill material was compacted.
2. Flat grading in the backfill zone.
3. Roof leaders discharged 1.5 m from the foundation wall.

Benchmark testing was also used to confirm the repeatability of the test results and to confirm the validity of the test procedure. The results of the benchmark testing are discussed in Section 3.

Remainder of Field Testing

During Phase II, rainfall events were simulated and the flow in the foundation drain before, during, and after the rainfall events was recorded. The following tasks describe the test procedure:

- The initial schedule of testing (Figure 3) was revised, based on the benchmark testing regime. The revised schedule is depicted in flowchart form by Figure 11.
- Decide the flowrate of water to be distributed over the front yard and back yard, from the manifold system and from the downspouts.
- Ensure that the on/off sensors connected to the sump pumps are functioning properly.
- Ensure that all water level recorders are functioning properly.
- Lay out soaker hoses to ensure even coverage of the lot and run hoses to the downspout discharge points.

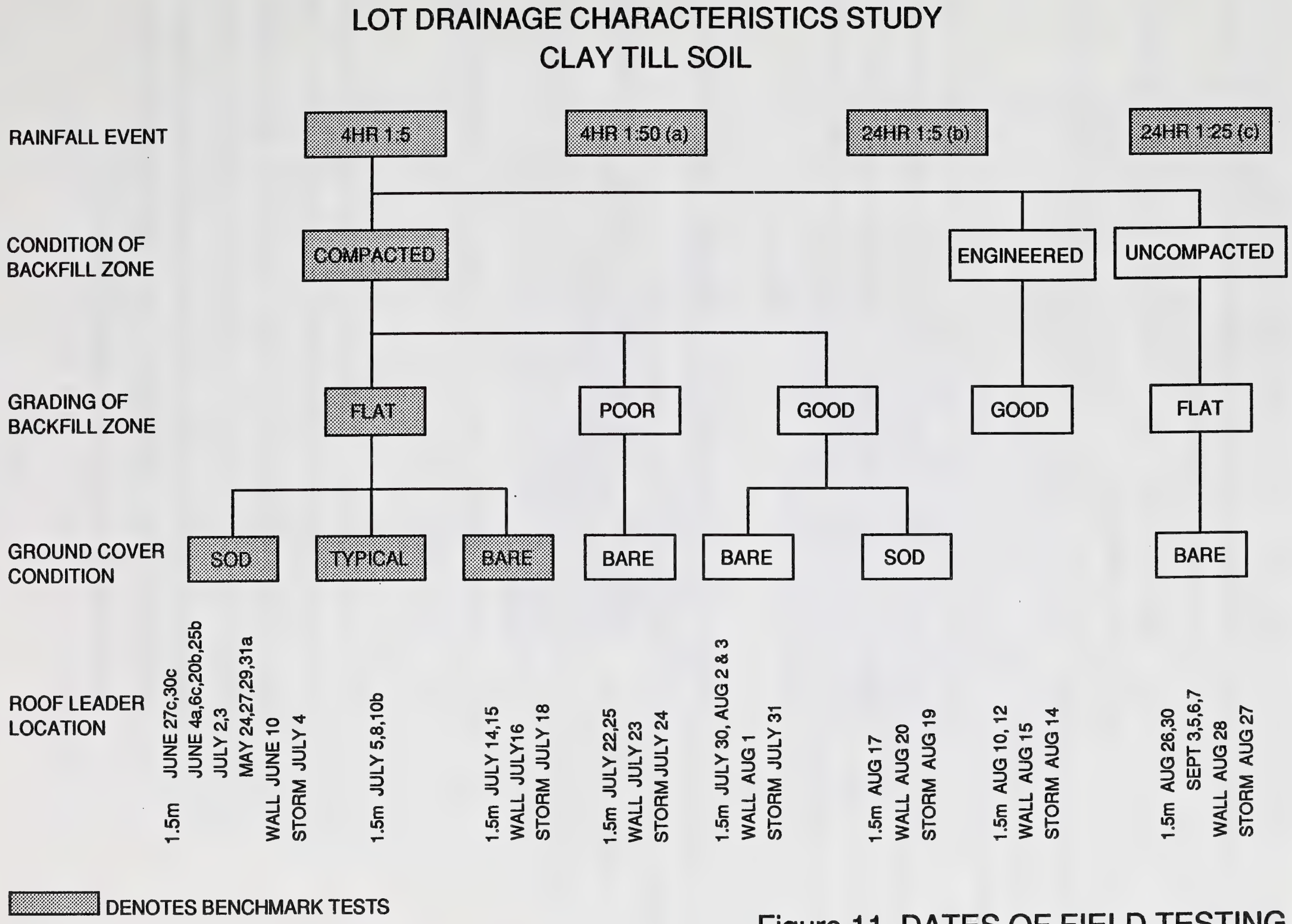


Figure 11 DATES OF FIELD TESTING

- Start flow from the fire hydrant and open valves on the manifolds until the flow through the meters reaches the values calculated in Figure 4a and 4b.
- Adjust the valves for the desired flowrate for the test design hyetograph.
- After the storm, determined by the volume of rainfall, stop the flow of water from the fire hydrant.

The on/off meters and the water level recorders were read at the beginning of the testing program and left in place until the end of the testing program. The advantage of leaving the meters installed was that the foundation drain flows were recorded during naturally occurring rainfall events.

Based on the above sequence, the individual tests were conducted and monitored as follows:

- Rainfall events were simulated by applying water with the soaker hoses and oscillating sprinklers.
- Sixteen piezometers were monitored to find groundwater responses.
- On/off current sensors on the sump pumps recorded sump pump running time.

At the start of each test the water level in the piezometers was read and the base flowrate of the foundation drain was determined. The site was then configured for the given test. One of the rainfall simulations shown on Figures 5, 6, 7 and 8 was carried out and the piezometer and pump on/off readings were stored on the data loggers. The data loggers were downloaded the following day and the data was then translated using the manufacturer's software.

Sump water was discharged to the surface, into a drainage ditch immediately east of the research facility. Discharge water did not re-enter the foundation drain system.

Since soil moisture conditions before a rainfall event may be a contributing factor to foundation drain response, the definition of antecedent soil moisture condition was necessary. Previous studies had defined dry antecedent conditions as the moisture content of the surface soils after a minimum of 3 days without rain, and that definition was adopted for this work. Borehole testing and infiltration tests were conducted during the testing program to provide a record of soil moisture conditions. Soil moisture test results are presented in Appendix C.

Site equipment monitored the groundwater, sump water level, and pump running time for both simulated and natural events. The equipment recorded relevant data 24 hours per day. Throughout the testing program the equipment performed satisfactorily, and the data record was complete. Photos 4 through 9 illustrate various test assemblies.

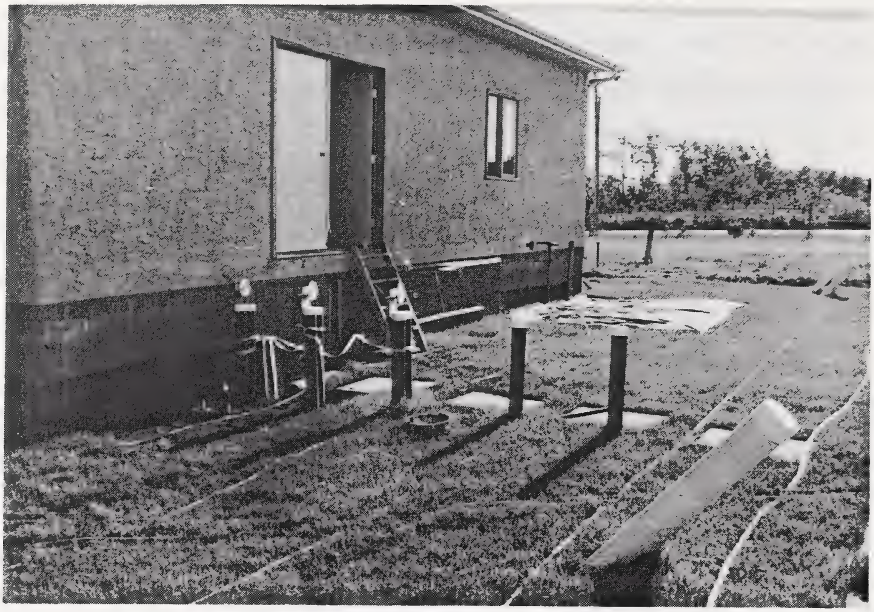


Photo 4. Piezometers - The five back-yard piezometers are pictured. The three piezometers in the backfill zone are equipped with a pulley-float-counterweight assembly that make up water level recorders.

Photo 5. Raingauge - Raingauge Station 90 was established onsite May 8, 1991. The station had a Rimco raingauge complete with data logger. The portable computer for downloading is also in the photo.

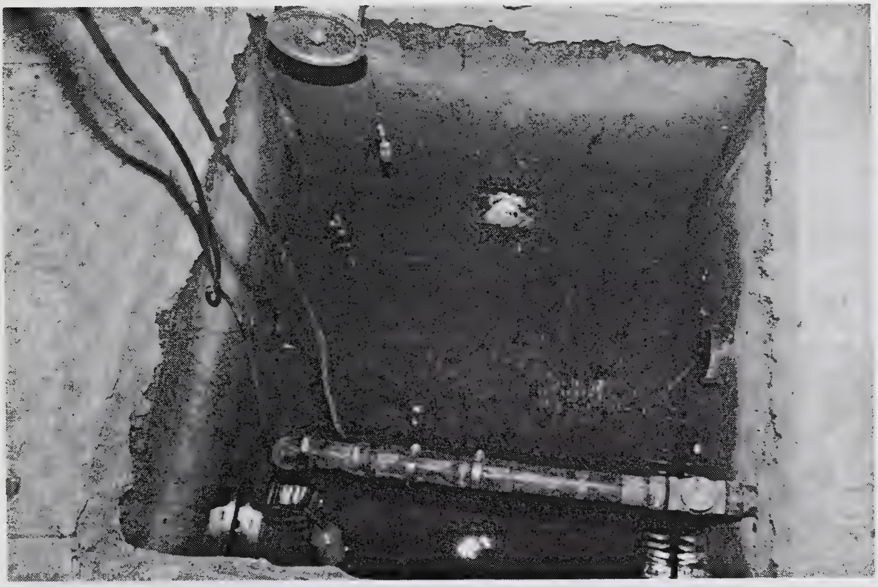


Photo 6. Water Level Recorder - The water level recorders are a pulley-float-counterweight assembly. The pulley's fixed axle has a potentiometer that indirectly reads water level as the float moves up and down.

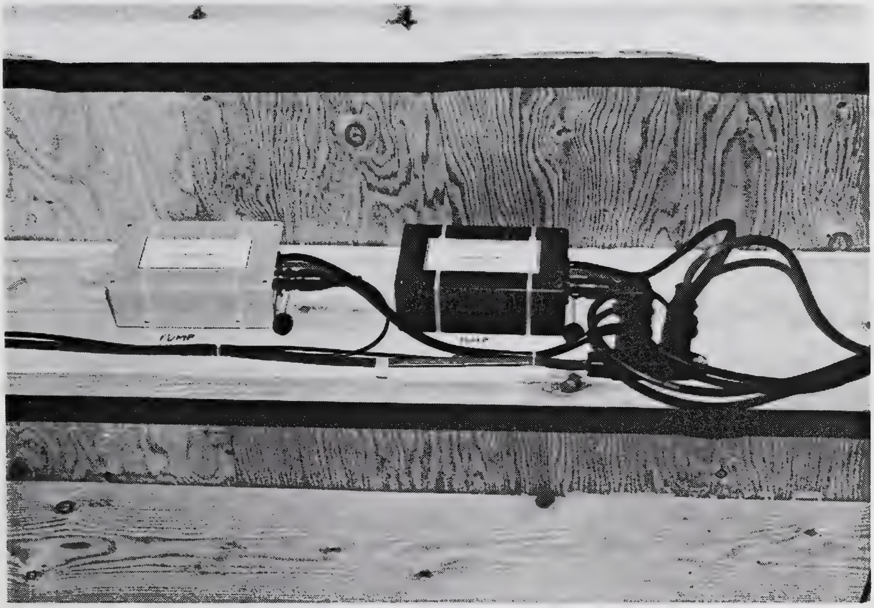


Photo 7. On/off Current Sensor - The on/off current sensors for the sump pumps record the time of pump starts and stops. Pump cycle time and foundation drain discharge volumes are also measured.

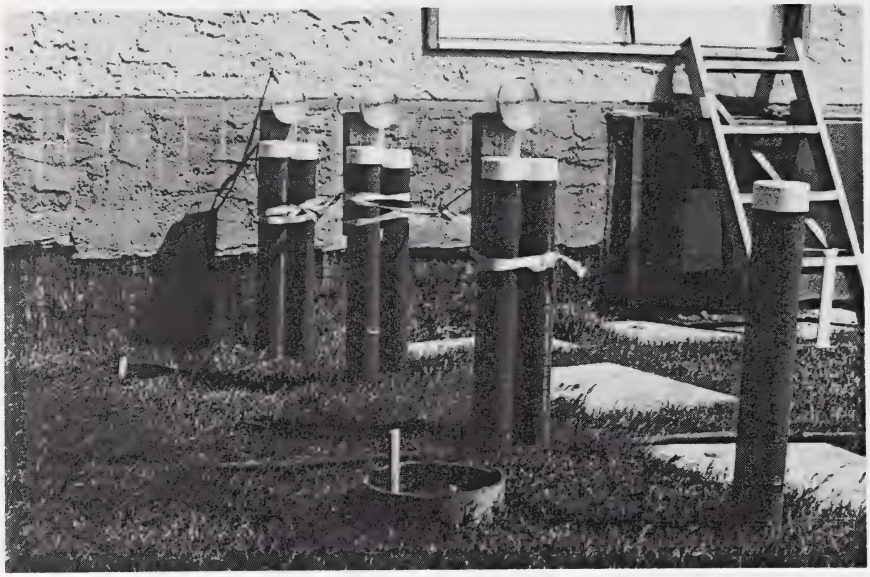


Photo 8. Infiltrometer - Two single ring, flooding type infiltrometers are marked by the survey stakes. PVC pipes were driven into the backfill zone and native soil to quantify infiltration rates.

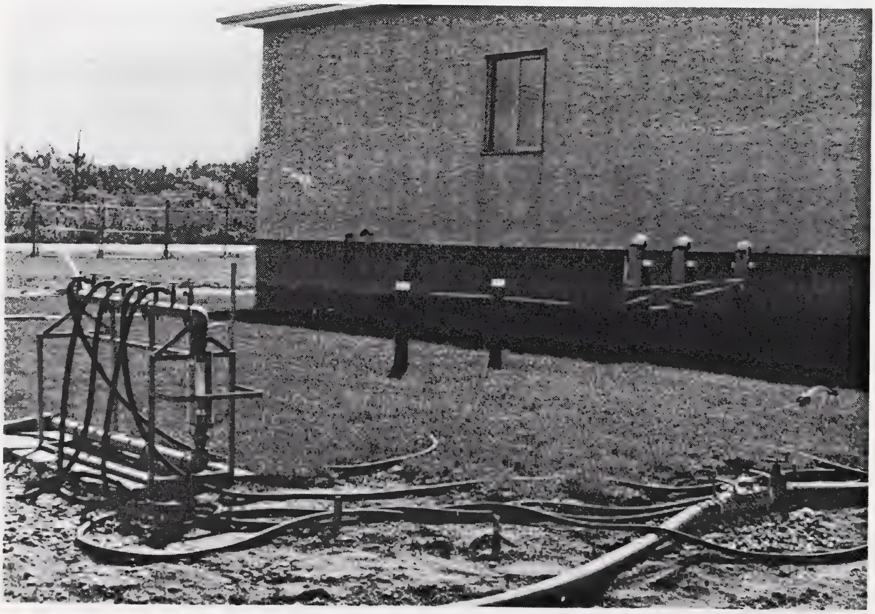


Photo 9. Rainfall Simulation Manifold - This photograph pictures one of four rainfall simulation manifolds complete with a variable area flowmeter. In the bottom right hand corner is the volume water meter on the fire hose.

2.3 Site Changes

Changes to the site for the various lot conditions required different levels of effort for both manpower and equipment. The site change from compacted clay till backfill to uncompacted clay till backfill required a Gradall, two tandem trucks, a wheeled backhoe, and four labourers. In comparison, the site change from a 1.5-m extension on the roof leaders to no extension, discharge at the foundation wall required the simple removal of the extensions. The following series of photographs (Photos 10 to 17 inclusive) show some of the site changes undertaken throughout the testing program.

Photo 10. Garden Tractor Doing Site Change - Small equipment such as skid loaders and the garden tractor above were used for lot grading and ground cover changes. The tractor is rototilling the sod to convert the backfill zone from sod to bare ground.

Photo 11. Completed Site Change - This photo shows the site after the rototilling was completed. The backfill zone has been changed to a flat grade, bare ground cover lot condition.

Photo 12: Typical Ground Cover - For the typical ground cover conditions the site was landscaped to have a combination of patio and driveway, sod and flower beds. This picture of the back-yard shows the poly sheeting used to simulate the patio.

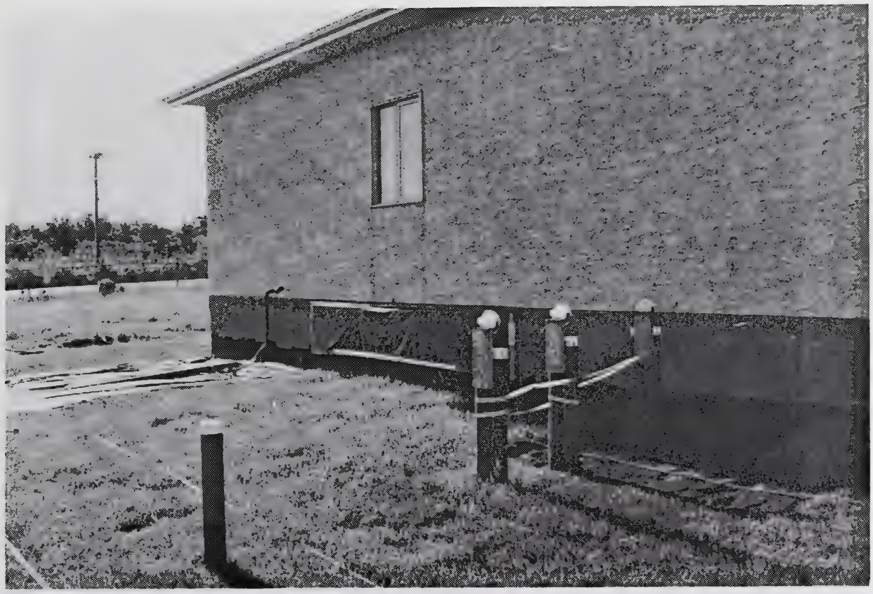


Photo 13. Typical Ground Cover - This is the front-yard of the typical ground cover condition. The poly sheeting on the left simulates a paved driveway and the bare ground at the bottom right is a flower bed.

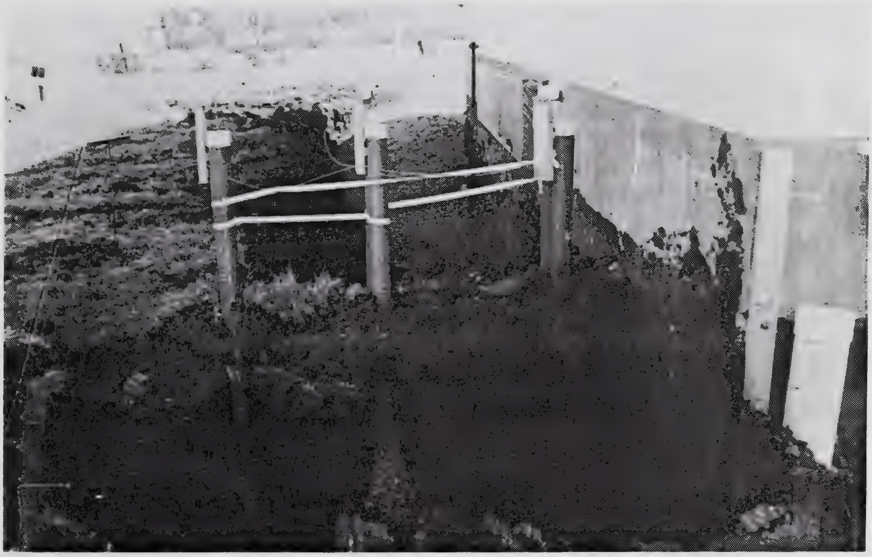


Photo 14. Excavation of Backfill Zone - To change from compacted clay till to uncompacted clay till, the backfill zone was excavated to original soil horizontally and to the foundation drain vertically. End dump backfilling of dry clay till, followed by surface grading, yielded the uncompacted backfill condition.

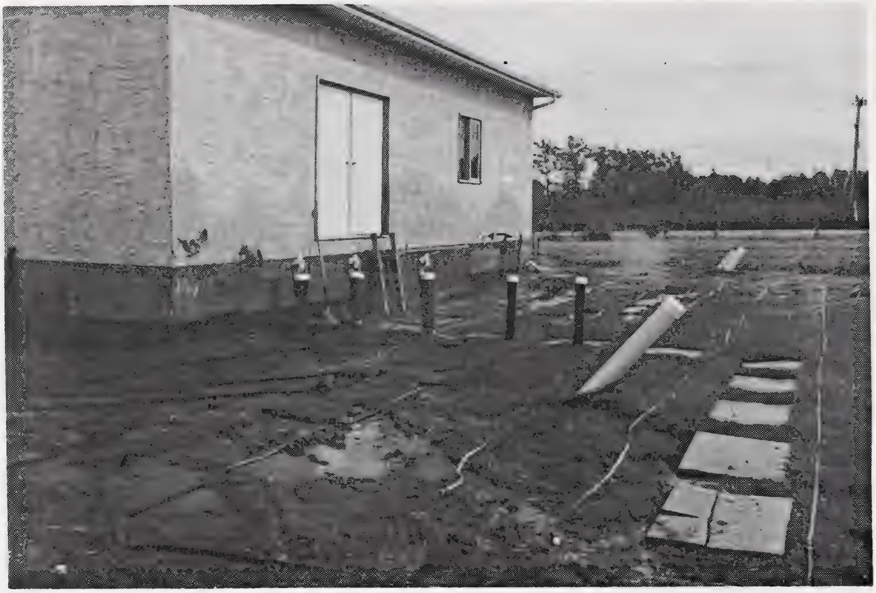


Photo 15. Uncompacted Backfill Zone - The site changes from compacted to uncompacted backfill left the site with some rutting caused by the heavy equipment.

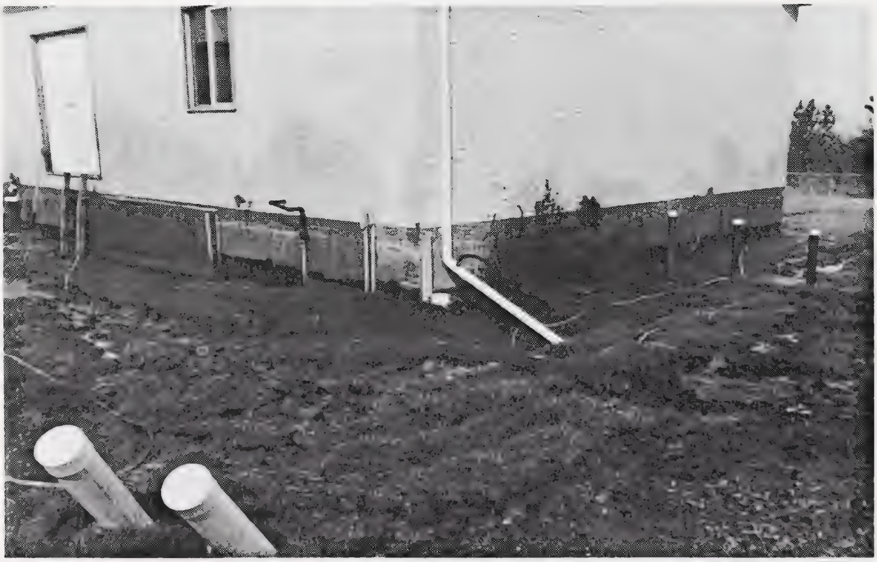


Photo 16. Roof Leader Extension - To simulate roof leader conditions, a hose with an appropriate flowrate was connected to the downspout, with a 1.5-m extension, as illustrated in this photo. To simulate roof leaders connected to a storm sewer, the valve for the hose was turned off.

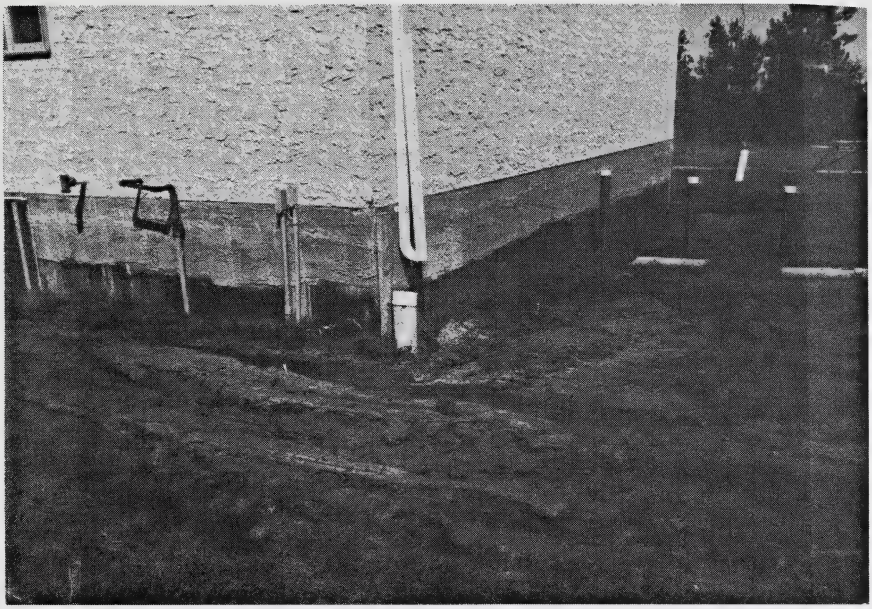


Photo 17. Roof Leader Discharging at Wall - To simulate roof leaders discharging at the wall, the extension was simply folded as illustrated.

3.0 TEST RESULTS AND ANALYSIS

This section of the report describes the testing program results and the analysis of the results and is presented in the following sequence:

- Section 3.1 discusses the problems encountered during testing
- Section 3.2 describes how the test records are interpreted
- Section 3.3 presents the analysis of the benchmark testing
- Sections 3.4 through 3.9 present the analysis of the test data for:
    1. Compaction of the backfill zone
    2. Grading of the backfill zone
    3. Location of roof leaders
    4. Ground cover of the backfill zone
    5. Groundwater response and antecedent moisture condition.

3.1 Problems Encountered

There were few problems encountered during the field testing program and the problems that did arise were either resolved during testing or accounted for in the interpretation of data. The problems encountered were:

1. Accurate recording of foundation drain flows, for flowrates less than 0.04 L/s, was not possible with the pump on/off sensors. During initial testing of compacted clay till soil, the inflow rate was very low and there were insufficient pump on/off cycles to adequately define a peak. As a result of the compacted backfill condition and larger sump sizes, the pumps would cycle as few as three times during a 4-hour test. Therefore, there was an insufficient number of data points to derive a response hydrograph. To provide an accurate record of response, water level recorders were installed in the sumps. Data loggers recorded the water level in the sumps every 4-min and at the pump start/stops, providing sufficient data to accurately calculate the inflow

rate and develop hydrographs.

2. Above normal natural rainfall during June delayed the testing schedule and required the separation of the collected data into simulated test data and natural event data for the days when rainfall overlapped simulations. Natural rainfall during the month of June was significantly above average. Figure 12 describes the natural rainfall record for the site. The rainfall delayed the testing program by approximately 20 days and required the separation of the collected data into simulated test data and natural event data for the days when rainfall overlapped simulations. The natural rainfall events will provide valuable information in calibrating the results of the simulated rainfall events as planned in Project 4 of the study. The June rainfall benefitted the test site by thoroughly wetting the soil. As discussed in the soils report, Appendix C, the site stratigraphy was unusual. The site was a fill area and the soil moisture contents were quite low. The above normal precipitation in June raised soil moisture closer to typical conditions.

3. One of the objectives of the research was to determine if antecedent soil moisture conditions affect foundation drain response. Wet soil conditions, caused by both heavy rainfall and test simulations, provided few opportunities for testing dry antecedent conditions for clay till soils. Over the 107-calendar-day testing period, the equivalent of 2188 mm of natural and simulated rain fell on the site. Over the summer 1107 m^3 of test water was applied to the site. The average precipitation (natural and simulated) over the testing period was 20.5 mm/d. With this amount of precipitation, dry antecedent conditions were infrequent and difficult to define. A scheduling decision to advance the testing without dry antecedent conditions was made since opportunities for testing dry antecedent conditions were probable in the subsequent testing (Projects 2 and 3). Additional observations and

RAINFALL CALIBRATION DATA
FOUNDATION DRAINAGE STUDY

Below is a list of calibration measurements made at the raingauge site.

Friday May 24	3.175mm	0.125inches	8:45PM
Friday May 31	4.000mm	0.157inches	1:45PM
Friday June 7	5.969mm	0.235inches	1:11PM
Monday June 10	62.484mm	2.460inches	9:45AM
Friday June 14	19.101mm	0.752inches	1:26PM
Friday June 21	?.???mm*	?.???inches*	
Friday June 28	34.290mm	1.350inches	1:35PM
Friday July 5	5.715mm	0.225inches	1:46PM
Friday July 12	2.032mm	0.080inches	1:17PM
Friday July 19	0.000mm	0.000inches	1:20PM
Friday July 26	2.286mm	0.090inches	2:32PM
Friday Aug 2	2.896mm	0.114inches	3:35PM
Friday Aug 9	3.607mm	0.142inches	1:21PM
Wed Aug 14	53.848mm	2.12inches	1:46PM
Friday Aug 23	15.900mm	0.626inches	4:21PM
Friday Aug 30	5.969mm	0.235inches	2:02PM
Friday Sept 6	0.254mm	0.010inches	1:19PM
Friday Sept 13	?.???mm*	?.???inches*	
Friday Sept 20	9.906mm	0.390inches	1:07PM

* Data was not collected those days. Data was collected the following Friday.

Figure 12

monitoring in the subsequent projects may assist in quantifying the effect of antecedent conditions on foundation drain response.

As documented in Appendix C, antecedent moisture conditions were defined by soil infiltration rates and groundwater elevations in the backfill zone. After the initial wetting period of 30 to 60 min, the infiltration rate of the soil was constant and rates were similar for both the backfill zone and native soil. Groundwater table readings in the backfill zone did not correlate with antecedent conditions.

3.2 Data Interpretation

The testing program was carried out from May 24 to September 7, 1991. During this period 44 rainfall simulations were carried out. The simulations provided 70 data sets. A data set is a record of water applied and the resulting foundation drain response hydrograph. Of the 44 simulations, 18 tests were conducted using a single lot arrangement (one sump receiving inflow from the front and back lot) yielding 18 data sets and 26 tests used the split lot configuration (both sumps employed, separating front and back-lot flows) giving 52 data sets. Summarized data are presented later in this section and sample data sheets are presented in Appendix B.

3.2.1 Interpretation of Summary Figures

Figure 13, Summary of Simulations presents the overall test results and the test of July 8 is used throughout this section of the report as an example of how the data was processed and interpreted. Following are brief explanations of the column headings of Figure 13:

Test Date	Date of the simulation
Storm	Type of storm simulated

SUMMARY OF SIMULATIONS

TEST DATE	STORM	START TIME	VOLUME APPLIED (L)	INTENSITY APPLIED (mm/hr)	PEAK RECORDED INFLOW (L/s)	% ENTERING FOUNDATION DRAIN EXCLUDING NATURAL RAINFALL				TIME TO PEAK		COMPACTION	GRADING	GROUND COVER	ROOF LEADER LOCATION
						FRONT	BACK	TOTAL	BASEFLOW(EXCL.) TOTAL	Tp (min)	Pp (min)				
24-May	4-hr/5-yr	10:00	22040	40.38	0.0348			4.20				COMPACTED	FLAT	SOD	1.5m
27-May	4-hr/5-yr	09:30	22040	40.38	0.0366			5.00				COMPACTED	FLAT	SOD	1.5m
29-May	4-hr/5-yr	09:40	22040	40.38	0.0120			2.70				COMPACTED	FLAT	SOD	1.5m
31-May	4-hr/50-yr	12:15	39720	67.31	0.0590			1.70				COMPACTED	FLAT	SOD	1.5m
04-Jun	4-hr/50-yr	09:15	39720	67.31	0.0550			2.10				COMPACTED	FLAT	SOD	1.5m
10-Jun	4-hr/5-yr	10:45	22040	40.38	0.0179			1.70				COMPACTED	FLAT	SOD	WALL
20-Jun	24-hr/5-yr	03:00	35180	12.45	0.0517			6.28		400.46	40.46	COMPACTED	FLAT	SOD	1.5m
25-Jun	24-hr/5-yr	03:00	35180	12.45	0.0444			5.01		411.62	51.62	COMPACTED	FLAT	SOD	1.5m
27-Jun	24-hr/25-yr	03:00	54910	18.54	0.0845			5.21		417.20	57.20	COMPACTED	FLAT	SOD	1.5m
30-Jun	24-hr/25-yr	03:00	52100	18.54	0.0530			2.43		419.50	59.50	COMPACTED	FLAT	SOD	1.5m
02-Jul	4-hr/5-yr	12:30	22040	40.38	0.0739	1.58	2.53	2.18		96.49	21.49	COMPACTED	FLAT	SOD	1.5m
03-Jul	4-hr/5-yr	09:30	22040	40.38	0.0796	1.65	2.45	2.16		85.36	10.36	COMPACTED	FLAT	SOD	1.5m
04-Jul	4-hr/5-yr	10:30	22040	40.38	0.0974			1.90	1.56	81.64	6.64	COMPACTED	FLAT	SOD	STORM
05-Jul	4-hr/5-yr	11:30	22040	40.38	0.0854			2.11	1.77	76.08	1.08	COMPACTED	FLAT	TYPICAL	1.5m
* 08-Jul	4-hr/5-yr	09:45	22040	40.38	0.0679	1.54	1.97	1.81	1.48	90.92	15.92	COMPACTED	FLAT	TYPICAL	1.5m
10-Jul	24-hr/5-yr	03:00	35180	12.45	0.0274			1.63	1.00	400.46	40.46	COMPACTED	FLAT	TYPICAL	1.5m
14-Jul	4-hr/5-yr	12:00	22040	40.38	0.0384			1.51	1.18	103.91	28.91	COMPACTED	FLAT	BARE	1.5m
15-Jul	4-hr/5-yr	11:00	22040	40.38	0.0562	1.70	1.77	1.74	1.41	92.78	17.78	COMPACTED	FLAT	BARE	1.5m
16-Jul	4-hr/5-yr	08:10	22040	40.38	0.0672	0.83	2.16	1.67	1.34	89.07	14.07	COMPACTED	FLAT	BARE	WALL
18-Jul	4-hr/5-yr	08:00	22040	40.38	0.0305	1.07	1.06	1.07	0.73	111.34	36.34	COMPACTED	FLAT	BARE	STORM
22-Jul	4-hr/5-yr	15:25	22040	40.38	0.0429	2.43	5.53	4.39	4.05	115.05	40.05	COMPACTED	POOR	BARE	1.5m
23-Jul	4-hr/5-yr	09:30	22040	40.38	0.0346	2.50	3.94	3.41	3.07	79.79	4.79	COMPACTED	POOR	BARE	WALL
24-Jul	4-hr/5-yr	10:15	22040	40.38	0.0342	2.56	3.97	3.45	3.12	102.06	27.06	COMPACTED	POOR	BARE	STORM
25-Jul	4-hr/5-yr	14:30	22040	40.38	0.0415	3.22	3.61	3.47	3.13	92.78	17.78	COMPACTED	POOR	BARE	1.5m
30-Jul	4-hr/5-yr	11:00	22040	40.38	0.0156	0.39	1.63	1.18	0.84	105.77	30.77	COMPACTED	GOOD	BARE	1.5m
31-Jul	4-hr/5-yr	11:30	22040	40.38	0.0206	1.36	1.82	1.65	1.31	98.35	23.35	COMPACTED	GOOD	BARE	STORM
01-Aug	4-hr/5-yr	10:10	22040	40.38	0.1252	1.53	4.56	3.44	3.13	68.65	-6.35	COMPACTED	GOOD	BARE	WALL
02-Aug	4-hr/5-yr	10:00	22040	40.38	0.0233	1.34	1.57	1.49	1.15	89.07	14.07	COMPACTED	GOOD	BARE	1.5m
03-Aug	4-hr/5-yr	10:10	22040	40.38	0.0221	1.83	1.00	1.31	0.97	92.78	17.78	COMPACTED	GOOD	BARE	1.5m

Figure 13 SUMMARY OF SIMULATIONS

SUMMARY OF SIMULATIONS

TEST DATE	STORM	START TIME	VOLUME APPLIED (L)	INTENSITY APPLIED (mm/hr)	PEAK RECORDED INFLOW (L/s)	% ENTERING FOUNDATION DRAIN EXCLUDING NATURAL RAINFALL				TIME TO PEAK		COMPACTION	GRADING	GROUND COVER	ROOF LEADER LOCATION
						FRONT	BACK	TOTAL	BASEFLOW(EXCL.) TOTAL	Tp (min)	Pp (min)				
10-Aug	4-hr/5-yr	13:05	22040	40.38	0.0209	0.30	2.29	1.56	1.23	100.20	25.20	ENGINEERED	GOOD	SOD	1.5m
12-Aug	4-hr/5-yr	09:05	22040	40.38	0.0132	0.41	1.19	0.90	0.57			ENGINEERED	GOOD	SOD	1.5m
14-Aug	4-hr/5-yr	10:55	22040	40.38	0.0123	0.50	1.09	0.87	0.54	103.91	28.91	ENGINEERED	GOOD	SOD	STORM
15-Aug	4-hr/5-yr	10:35	22040	40.38	0.0275	0.41	1.31	0.98	0.64	87.21	12.21	ENGINEERED	GOOD	SOD	WALL
17-Aug	4-hr/5-yr	14:50	22040	40.38	0.0089	0.69	0.54	0.60	0.26			COMPACTED	GOOD	SOD	1.5m
19-Aug	4-hr/5-yr	09:40	22040	40.38	0.0150	0.72	0.85	0.80	0.47	102.60	27.60	COMPACTED	GOOD	SOD	STORM
20-Aug	4-hr/5-yr	11:15	22040	40.38	0.0745	1.23	3.54	2.69	2.36	92.78	17.78	COMPACTED	GOOD	SOD	WALL
26-Aug	4-hr/5-yr	13:20	22040	40.38	0.7005	16.87	17.64	17.36	17.02	94.63	19.63	UNCOMPACTED	FLAT	BARE	1.5m
27-Aug	4-hr/5-yr	10:45	22040	40.38	0.4457	10.50	13.59	12.46	12.12	111.34	36.34	UNCOMPACTED	FLAT	BARE	STORM
28-Aug	4-hr/5-yr	09:45	22040	40.38	1.1219	46.02	22.06	30.87	30.56	81.64	6.64	UNCOMPACTED	FLAT	BARE	WALL
30-Aug	4-hr/5-yr	09:50	22040	40.38	1.0315	26.92	27.81	27.48	27.14	81.86	6.86	UNCOMPACTED	FLAT	BARE	1.5m
** 03-Sep	4-hr/5-yr	09:40	22040	40.38	0.8777			28.43	28.10	90.92	15.92	UNCOMPACTED	FLAT	BARE	1.5m
** 05-Sep	4-hr/5-yr	09:40	22040	40.38	2.7299			156.16	155.83	83.50	8.50	UNCOMPACTED	FLAT	BARE	1.5m
** 06-Sep	4-hr/5-yr	12:30	22040	40.38	2.3902			131.16	130.82	76.08	1.08	UNCOMPACTED	FLAT	BARE	1.5m
** 07-Sep	4-hr/5-yr	11:15	22040	40.38	2.7484			73.55	73.22	96.49	21.49	UNCOMPACTED	FLAT	BARE	1.5m

Note:
- * Test data used in examples on p.49 and Figure 14.
- ** Simulated rainfall with the sump pump discharging within the backfill zone resulted in recirculation of applied water. Total % entering foundation drain could exceed 100% of applied water.

Figure 13 SUMMARY OF SIMULATIONS (CONTINUED)

Start Time	Time test started
Volume Applied	Volume of water put on the site
Intensity Applied	Maximum intensity of storm hyetograph
Peak Recorded Inflow	Peak rate of inflow for simulation

The next six columns in Figure 13 are calculated values and are explained below.

% Entering Foundation Drain - Water level recorders were installed in both sumps to measure water levels at 4 min intervals. The area of the sump multiplied by the change in water level during the time interval is the volume of inflow during the interval. The rate of inflow is the volume divided by the time. The total volume of foundation drain inflow is the summation of the incremental volumes of water over the test period (the test period was a 12-hour duration commencing at the test start time). The percent entering the drain is the volume of inflow received at the sump divided by the volume of water applied to the site. The Front and Back columns are the ratios of the volume applied to inflow received for the front and back lots respectively in the split-lot configuration.

The Total column is either the ratio for the single site configuration or the accumulation of front and back-lot inflows for the split lot data.

The Total - Baseflow Excluded column is the ratio of volume entering minus the baseflow to the volume applied, expressed as a percent. After the initial test simulations, the backfill soil was sufficiently wetted to yield a constant flow (baseflow) to the foundation drain. This baseflow was subtracted from the volume of inflow water for each simulation to yield the storm-induced inflow.

Time to Peak - The timing of the storm-induced response is an important value in drainage engineering and was recorded for each test. The time of maximum inflow was visually interpreted from the individual response hydrographs and measured from the start of the rainfall simulation (Tp) and from the time of maximum intensity of the storm hyetograph (Pp).

The remaining columns of the summary sheets are the site conditions for the simulation.

3.2.2 Interpretation of Inflow Hydrographs

The data from each simulation were analyzed and inflow (response) hydrographs were developed. The hydrographs were derived from the measured inflow data; therefore, they include baseflow components. Sample inflow hydrographs are shown by Figures 14 to 16.

The response hydrographs show the rainfall induced inflow to the foundation drain in relation to the time of the storm event. The hydrographs have two vertical scales. The main scale shows the rate of inflow in litres per second. The one in italics shows the precipitation intensity in millimetres per hour. The inflow rate is plotted as a line on the graph; precipitation is shown as a hatched area at the top, indicating the intensity and duration of the simulated event. The lot characteristics for the simulation are presented in the top right hand corner of the graph.

The response hydrograph shows the inflow rate throughout the storm and the area under the curve is the volume of water conveyed through the foundation drain. As previously described, dividing the volume of

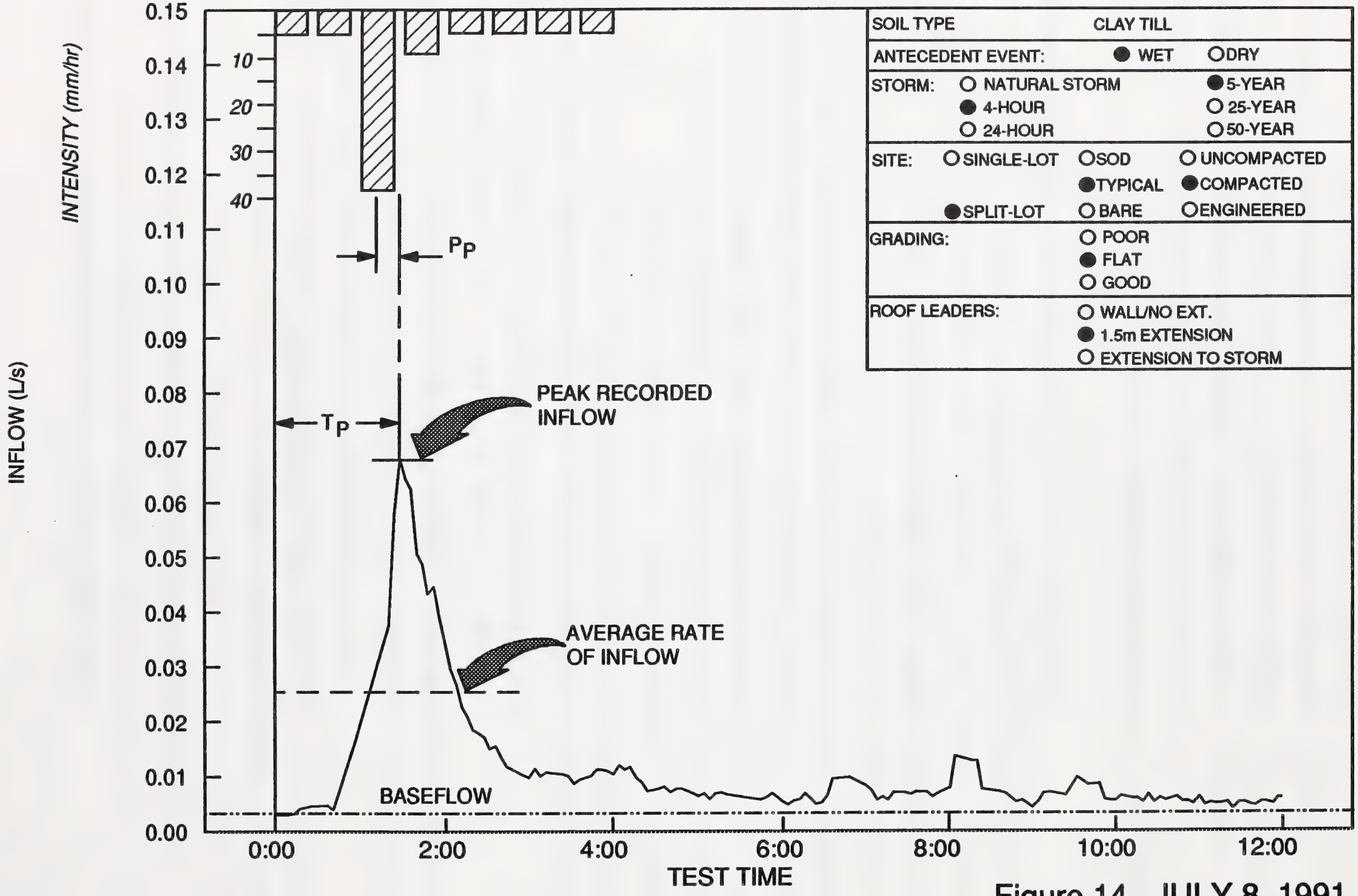


Figure 14 JULY 8, 1991
TOTAL-LOT

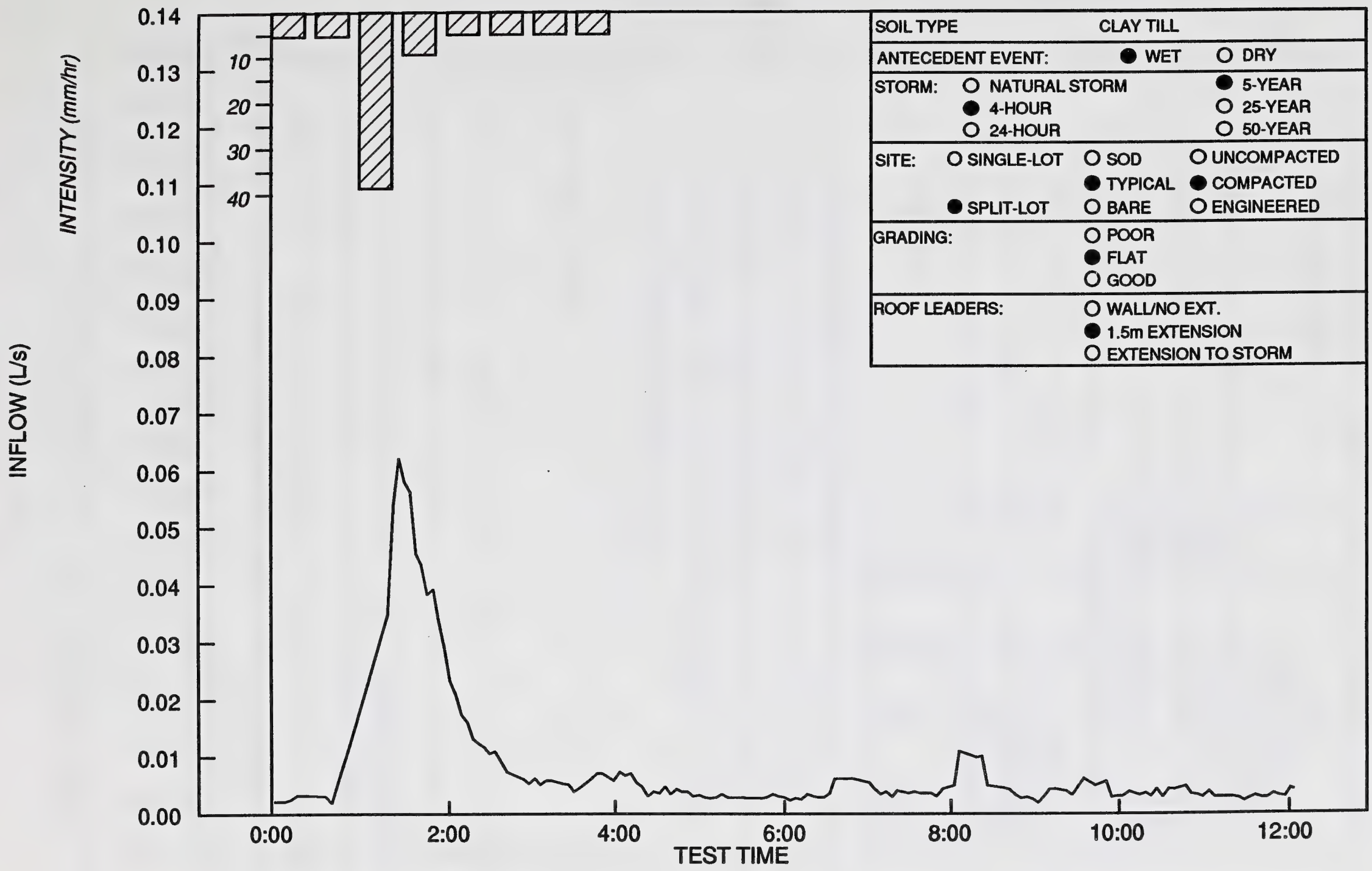


Figure 15 JULY 8, 1991
BACK-LOT

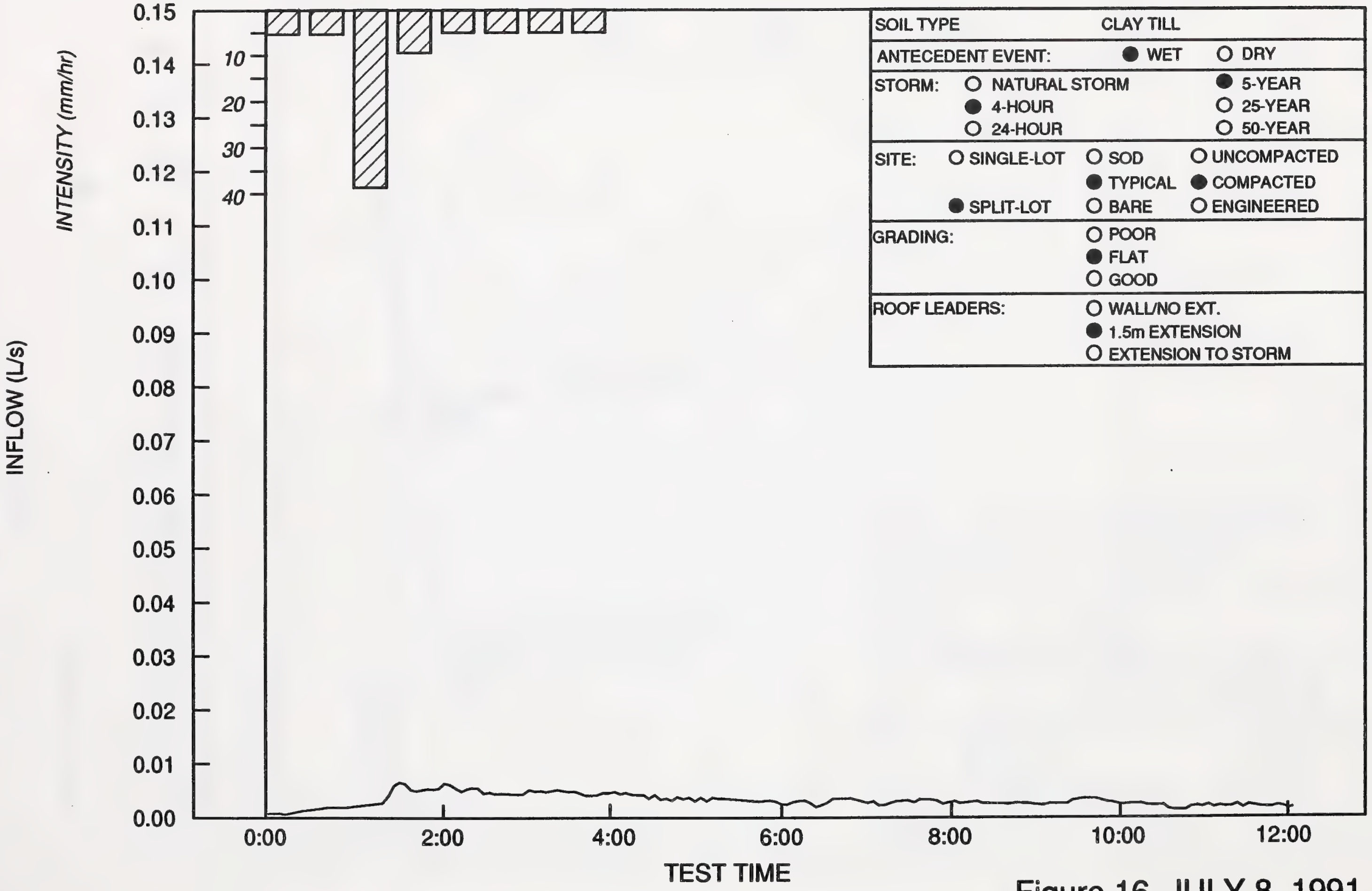


Figure 16 JULY 8, 1991
FRONT-LOT

inflow by the water applied yields the percent of water entering the foundation drain.

Figure 14 is labelled to identify the values listed on Figure 13. For example, peak recorded inflow, time to peak from start of test (Tp), time to peak from peak intensity (Pp), and baseflow are labelled on the response hydrograph. The lot configuration (characteristics as described in Section 2.0) for the test is detailed in the top right-hand corner of each graph. To illustrate, the values of peak inflow and Pp for July 8 from Figures 13 and 14 are 0.0679 L/s and 15.92 min respectively.

A split lot, dual sump arrangement was used during 26 of the test days. The division of the site into front and back lots provided a detailed breakdown of which part of the site contributes what portion of the inflow. Figure 14 is derived by combining back-lot (Figure 15) and front-lot (Figure 16) inflow values.

3.3 Benchmark Testing

An objective of benchmark testing was to limit the number of tests by evaluating certain variables in terms of whether the foundation drain responses measured could be used to accurately predict the responses to other variables in the same category for the same lot conditions. Benchmark testing examined the effect of storm type, lot configuration and ground cover on foundation drain response. Benchmark testing was also used to confirm that the results were repeatable for given lot conditions and, by so doing, confirming the validity of the test procedure.

Figure 17 summarizes the benchmark test simulations. The following

SUMMARY OF SIMULATIONS

TEST DATE	STORM	START TIME	VOLUME APPLIED (L)	INTENSITY APPLIED (mm/hr)	PEAK RECORDED INFLOW (L/s)	% ENTERING FOUNDATION DRAIN EXCLUDING NATURAL RAINFALL				TIME TO PEAK		GROUND COVER	ROOF LEADER LOCATION
						FRONT	BACK	TOTAL	BASEFLOW(EXCL.) TOTAL	Tp	Pp		
										(min)			
24-May	4-hr/5-yr	10:00	22040	40.38	0.0348			4.20				SOD	1.5m
27-May	4-hr/5-yr	09:30	22040	40.38	0.0366			5.00				SOD	1.5m
29-May	4-hr/5-yr	09:40	22040	40.38	0.0120			2.70				SOD	1.5m
31-May	4-hr/50-yr	12:15	39720	67.31	0.0590			1.70				SOD	1.5m
04-Jun	4-hr/50-yr	09:15	39720	67.31	0.0550			2.10				SOD	1.5m
10-Jun	4-hr/5-yr	10:45	22040	40.38	0.0179			1.70				SOD	WALL
20-Jun	24-hr/5-yr	03:00	35180	12.45	0.0517			6.28		400.46	40.46	SOD	1.5m
25-Jun	24-hr/5-yr	03:00	35180	12.45	0.0444			5.01		411.62	51.62	SOD	1.5m
27-Jun	24-hr/25-yr	03:00	54910	18.54	0.0845			5.21		417.20	57.20	SOD	1.5m
30-Jun	24-hr/25-yr	03:00	52100	18.54	0.0530			2.43		419.50	59.50	SOD	1.5m
02-Jul	4-hr/5-yr	12:30	22040	40.38	0.0739	1.58	2.53	2.18		96.49	21.49	SOD	1.5m
03-Jul	4-hr/5-yr	09:30	22040	40.38	0.0796	1.65	2.45	2.16		85.36	10.36	SOD	1.5m
04-Jul	4-hr/5-yr	10:30	22040	40.38	0.0974			1.90	1.56	81.64	6.64	SOD	STORM
05-Jul	4-hr/5-yr	11:30	22040	40.38	0.0854			2.11	1.77	76.08	1.08	TYPICAL	1.5m
08-Jul	4-hr/5-yr	09:45	22040	40.38	0.0679	1.54	1.97	1.81	1.48	90.92	15.92	TYPICAL	1.5m
10-Jul	24-hr/5-yr	03:00	35180	12.45	0.0274			1.63	1.00	400.46	40.46	TYPICAL	1.5m
14-Jul	4-hr/5-yr	12:00	22040	40.38	0.0384			1.51	1.18	103.91	28.91	BARE	1.5m
15-Jul	4-hr/5-yr	11:00	22040	40.38	0.0562	1.70	1.77	1.74	1.41	92.78	17.78	BARE	1.5m
16-Jul	4-hr/5-yr	08:10	22040	40.38	0.0672	0.83	2.16	1.67	1.34	89.07	14.07	BARE	WALL
18-Jul	4-hr/5-yr	08:00	22040	40.38	0.0305	1.07	1.06	1.07	0.73	111.34	36.34	BARE	STORM

Figure 17 CLAY TILL SOIL
BENCHMARK COMPACTED FLAT

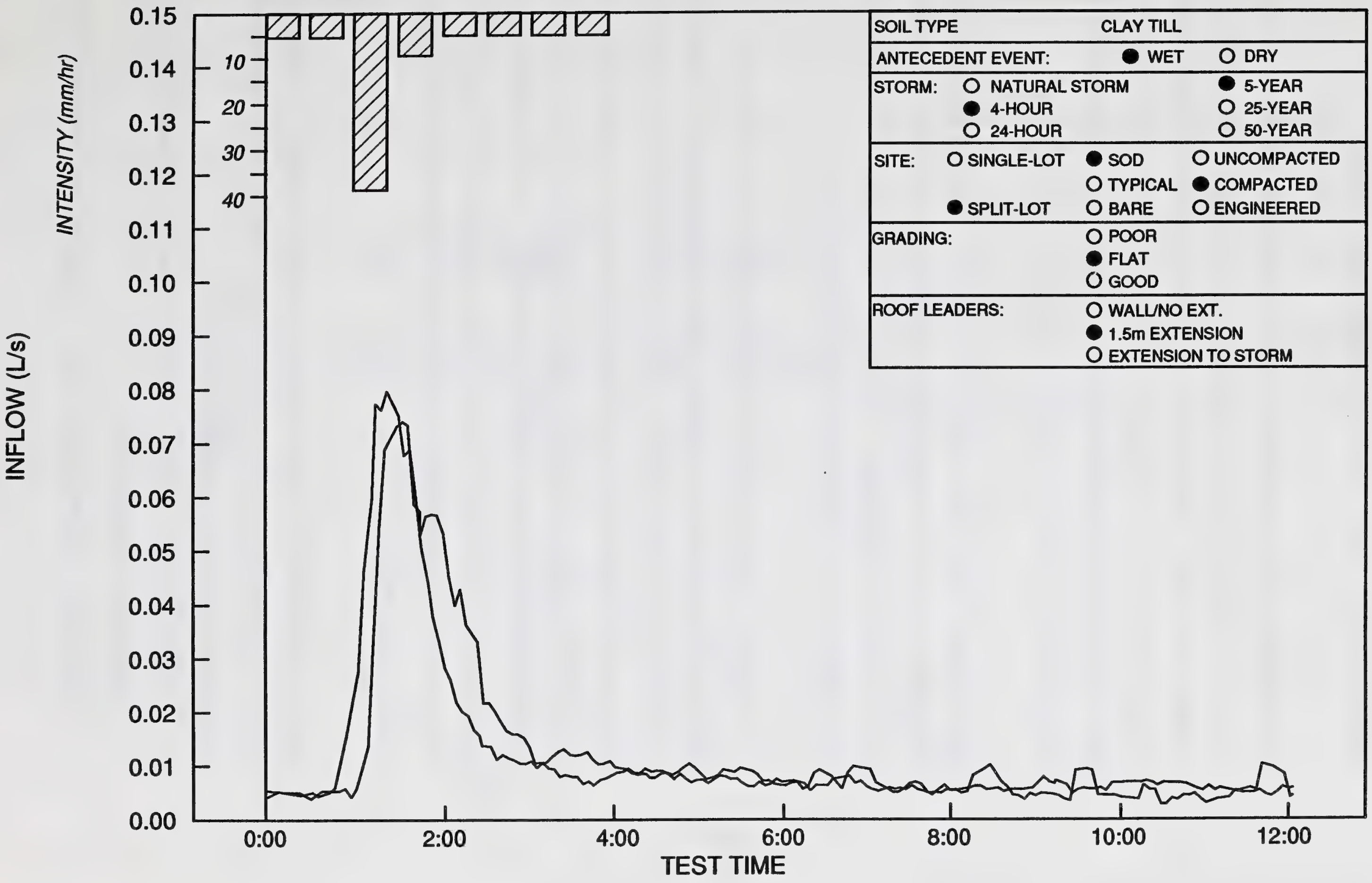


Figure 18 July 2 & 3

discussion presents the findings of the benchmark testing.

Repeatability of the Test Results The response hydrographs for July 2 and 3, Figure 18, illustrate that foundation drain responses could be duplicated at the research facility. Throughout the testing program, for each backfill lot configuration (i.e., compacted-poor-bare), the simulation with the 1.5 m roof leader location was conducted twice to check the accuracy of the test procedures and consistency of site characteristics (repeatability).

Storm Events Four storm events were tested to provide intensity-duration relationships to the foundation drain response, and to select the test storm for the balance of the testing. Figure 19 compares storm intensity-duration to foundation drain response for the four storm events.

The foundation drain response for both the short and long duration events shows the effect of intensity on the response hydrographs. As precipitation intensities rose and fell, so did the inflow. However, for clay till soil, the type of storm did not affect the rate of inflow for the events tested in the manner expected. The peak recorded inflows did not increase with the corresponding increase of intensity of the different storm events. The scheduled analysis of the natural rainfall events for clay till soil, a component of upcoming Project 4, may provide the additional data needed for quantifying the relationships between storm events.

Based on the findings of the benchmark testing, however, the 4-hour, 5-year event was selected as the test storm for the remainder of the project and for the future studies for the following reasons:

1. The foundation drain response for the storm was very distinct, as illustrated in Figure 18.
2. Personnel requirements needed to complete the 4 hour storm were less

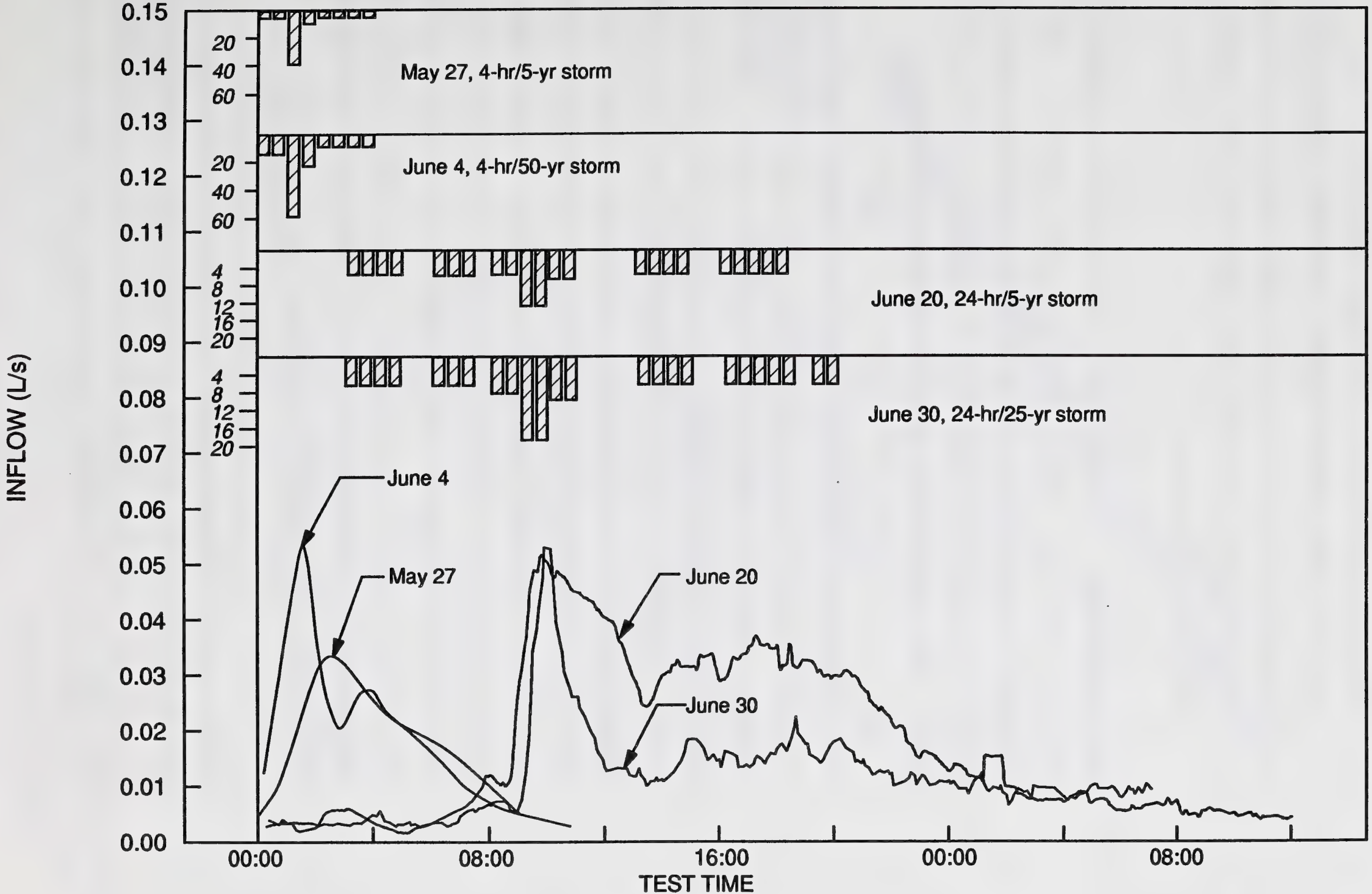


Figure 19 COMPARISON OF STORM EVENTS

demanding than those for the longer duration tests.

3. The 1991 testing schedule planned 70 test days; therefore, the total saturation of the site was a concern. The 4-hour, 5-year event applied 22 m^3 of water to the site per test, compared to 39.7 m^3 required for the 4-hour, 50-year event.

Lot Configuration It was anticipated that front-yard foundation drain responses would vary linearly with back-yard responses. Once this relationship was quantified, the site could then be regraded as two back yards (taking advantage of the research facilities design), thus doubling the rate of testing. This assumption was not borne out as described below.

With the single lot, back-to-front drainage configuration, front and back-lot inflows were recorded separately for 26 test days and individual response hydrographs derived as previously shown in Figures 14 to 16. The front and back-lot data for each simulation were evaluated using linear regression analysis. Sample plots of the linear regression analysis are presented by Figure 20 and the derived relationship is shown under each plot. The back-yard response was a linear function of the total lot inflow for all lot drainage characteristics. In contrast, the front-yard response was not linear to the total lot response (therefore not linear to the backyard response) and further, the relationship varied for each lot drainage characteristic. The initial assumption that back and front-lot inflow responses would be affected by the same lot characteristics was therefore not borne out. Testing proved that for back-to-front drainage, back-lot characteristics impact front-lot response.

Based on the findings, the standard lot configuration was established for subsequent testing. The standard chosen was a single lot with back-to-front drainage and both front and back-lot inflows were measured for the remainder of the clay till testing. This will also be the regime for the future

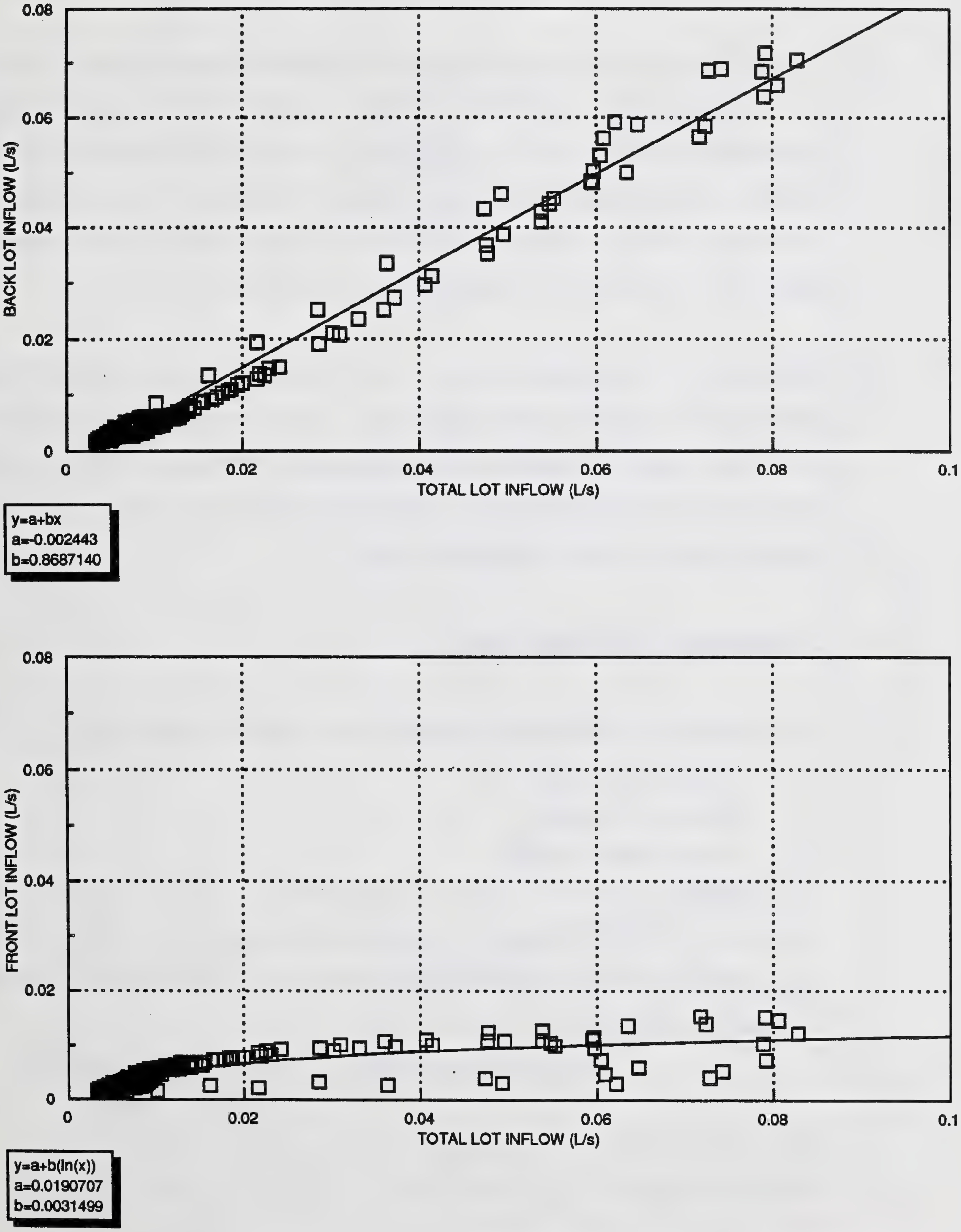


Figure 20 LINEAR REGRESSION COMPACTED, FLAT GRADING, SOD

studies (Projects 2, 3, and 4.)

Ground Cover In the initial planning of site changes, it was assumed that the site work required to establish a typical condition for each grading and compaction condition would be extensive. Testing could be expedited if sod and bare ground conditions were tested and compared to the typical lot. Benchmark test data was used to establish a relationship between typical ground cover response and sod ground cover response.

Simulations of the typical ground cover condition were conducted and compared to the sod condition (Figure 21). The foundation drain responses were very similar. Based on the test results, subsequent testing was conducted on sod ground cover (simulating landscaped yards) and bare ground (simulating new construction) only.

3.4 Compaction of the Backfill Zone

Three different backfill zone conditions were tested for clay till soil:

- Compacted backfill
- Engineered backfill
- Uncompacted backfill.

The conditions produced a much wider variation in flow responses than expected, as shown by Figure 22. Representative values for the peak inflow rate and the percentage entering the foundation drain for these backfill conditions are summarized below:

	Peak Recorded Inflow	Percentage entering the foundation drain
Compacted backfill	0.053 L/s	2.22
Engineered backfill	0.019 L/s	1.10
Uncompacted backfill	0.709 L/s	23.32

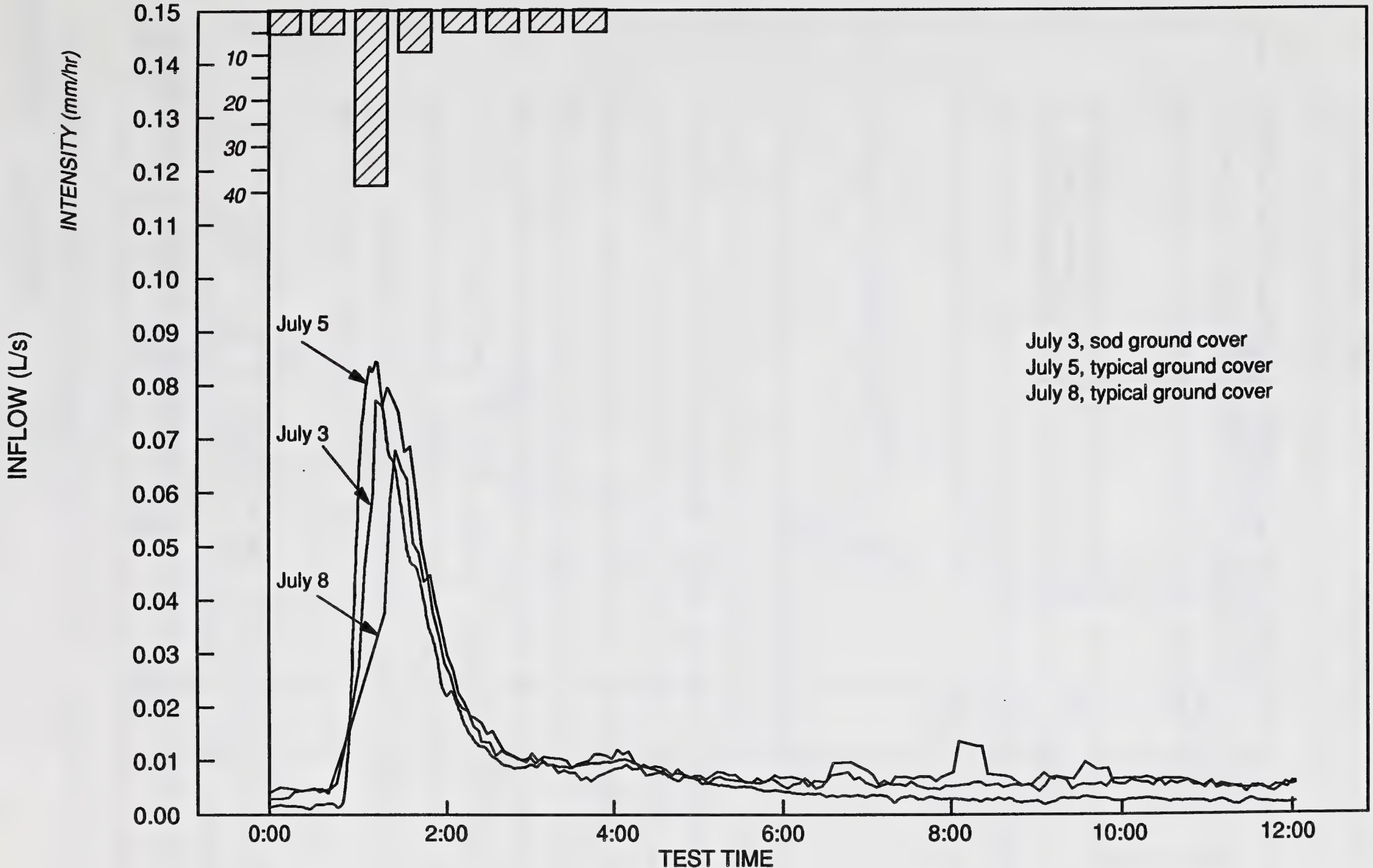


Figure 21 COMPARISON OF GROUND COVER

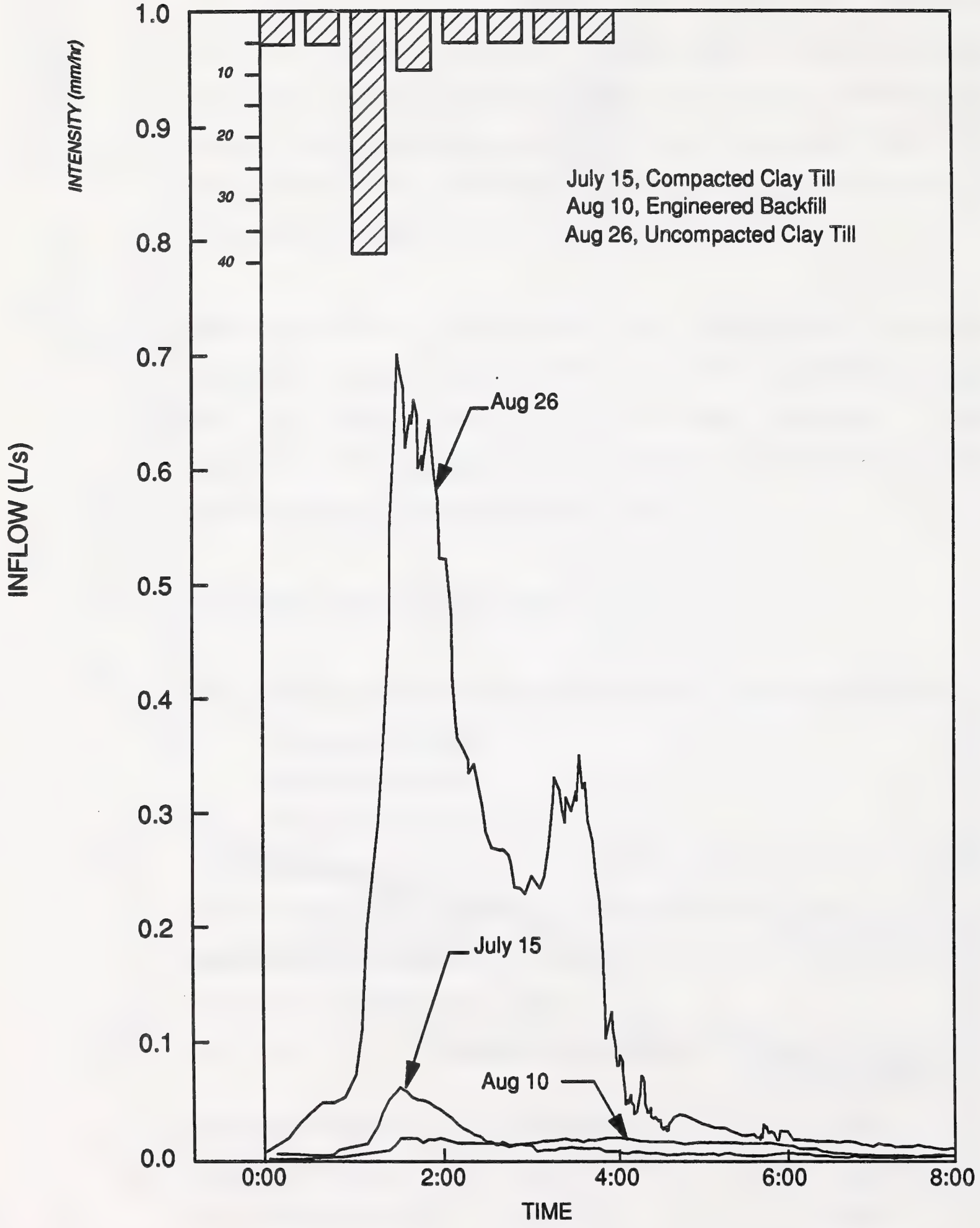


Figure 22 COMPARISON OF BACKFILL CONDITIONS

The peak flowrates measured at the research site were comparable to the values documented in the Winnipeg and Milwaukee studies. The above summary clearly shows the impact of uncompacted backfill on flowrates. The inflow for uncompacted backfill, typical to new homes, was almost 14 times greater than the foundation drain response for compacted backfill.

A limited number of tests were conducted on the engineered backfill test configuration and the foundation drain responses were significantly less than for other tests. Engineered backfill was tested for comparison purposes and the initial results indicate a potential benefit for lot regrading programs.

3.5 Grading of the Backfill Zone

The analysis for grading within the backfill zone considered foundation drain response data for the compacted, bare ground condition only. Test simulations on July 14 to 18 were used for the flat grading condition. Tests of July 22 to 25 provided data for the poor grading condition and the simulated events of July 30 to August 3 were used for good grading. Representative values for each grading condition are illustrated by Figure 23. For poor and flat grading, the tests did not produce the expected results - the average peak inflow rate for poor grading was less than the inflow rates observed for the flat site condition. Good grading produced the expected results - the average peak inflow was substantially less than for both the poor and flat grading conditions.

It was observed during the tests for poor grading that substantial amounts of water ponded along the foundation wall. In comparison there was only minor ponding for the flat grading and no water ponded for the good condition. Based on these observations, it was speculated, for poor grading in the backfill zone the only drainage path to the foundation drain was along the wall. For

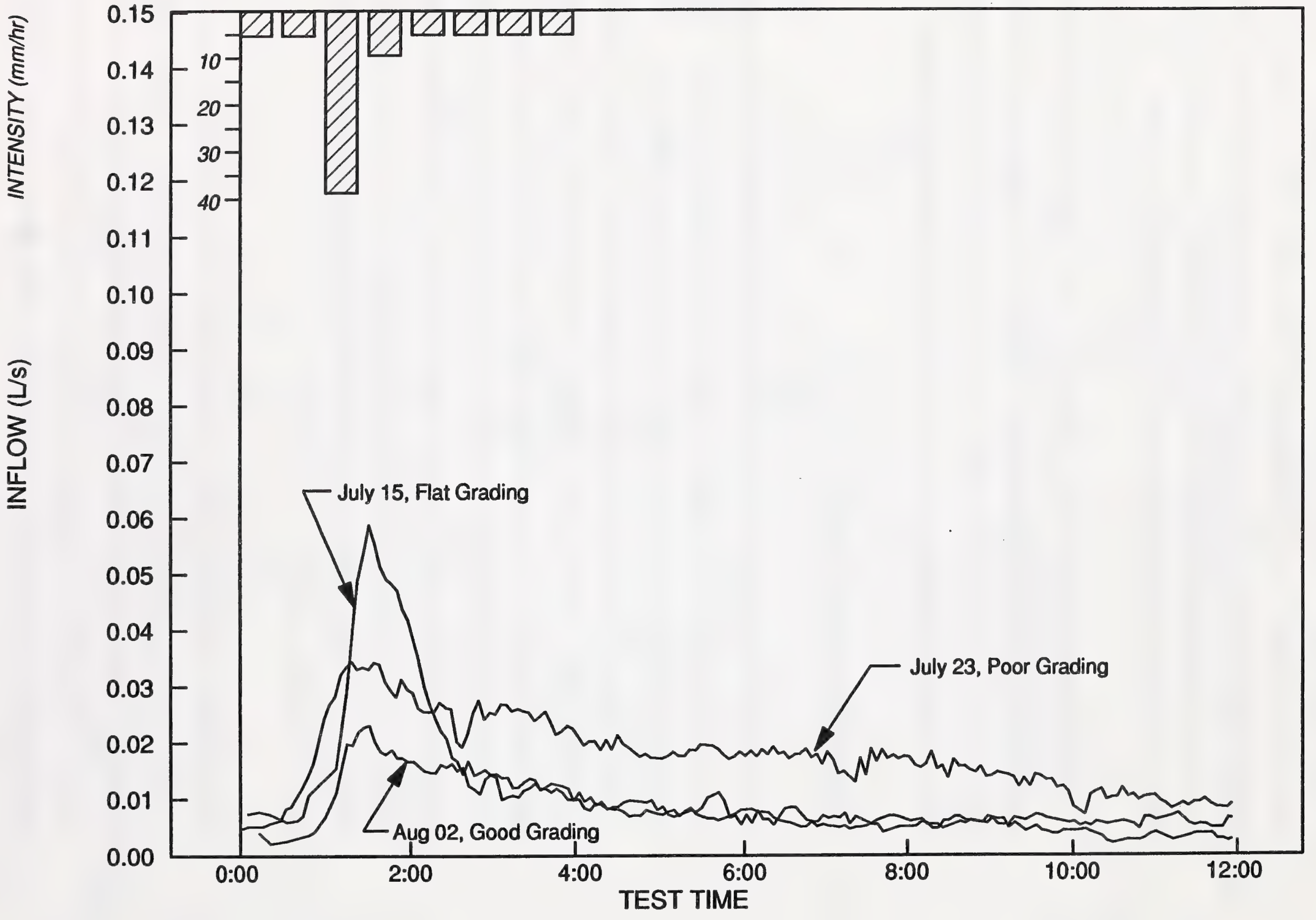


Figure 23 COMPARISON OF BACKFILL GRADING

the flat condition, water could flow to the drain along the wall and along the native soil - backfill zone boundary.

The average peak responses for the three grading conditions with bare-ground cover were 0.048 L/s for flat, 0.038 L/s for poor and 0.020 L/s for good.

The average percentage entering the foundation drain for the poor grading condition was 3.68. This was significantly greater than 1.67, which was the average of flat and good grading conditions. Results show that poor grading resulted in twice the volume of inflow compared to flat or good grading during storm events. The ponded water along the basement wall during the poor grading tests provided a reservoir of water that eventually entered the drain. For the flat and good grading condition, there was not a similar ponding of water. Therefore less water within the backfill zone entered the drain.

3.6 The Location of Roof Leaders

The locations at which the roof leaders discharged had a significant effect on both peak inflow rates and the time to peak. Figure 24 illustrates the effect of roof leader discharge locations on drain response. The average peak inflows recorded for the three roof leader discharge locations tested were:

- Discharge at wall - 0.067 L/s
- Discharge at 1.5 m from wall - 0.042 L/s
- Discharge to storm sewer - 0.023 L/s.

The time to peak was 22 min earlier for the roof leader discharging at the wall than the test condition where the roof leader was discharged to the storm sewer. Roof leaders discharging to storm sewers were a component of the testing program; however, individual storm services to residential lots is not a common practice in most municipalities.

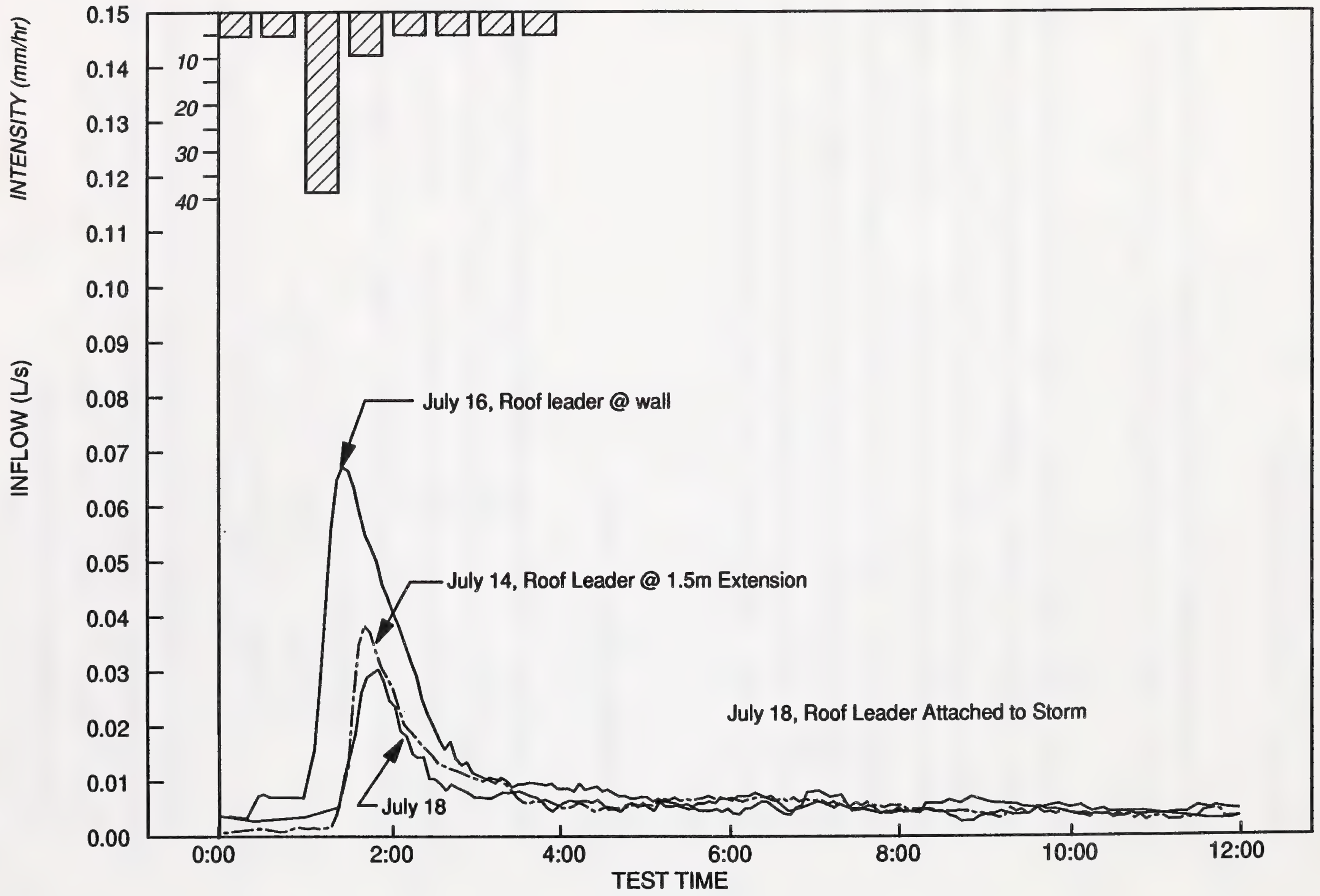


Figure 24 COMPARISON OF ROOF LEADER DISCHARGE LOCATION

The practice of discharging roof leaders adjacent to the basement wall increased the foundation drain response for all the lot configurations tested. This effect was less significant for the poor backfill grading conditions. For the good grading condition, when the discharge was simulated as connected to the storm sewer, there was a very small reduction in flowrate compared to a 1.5-m extension simulation.

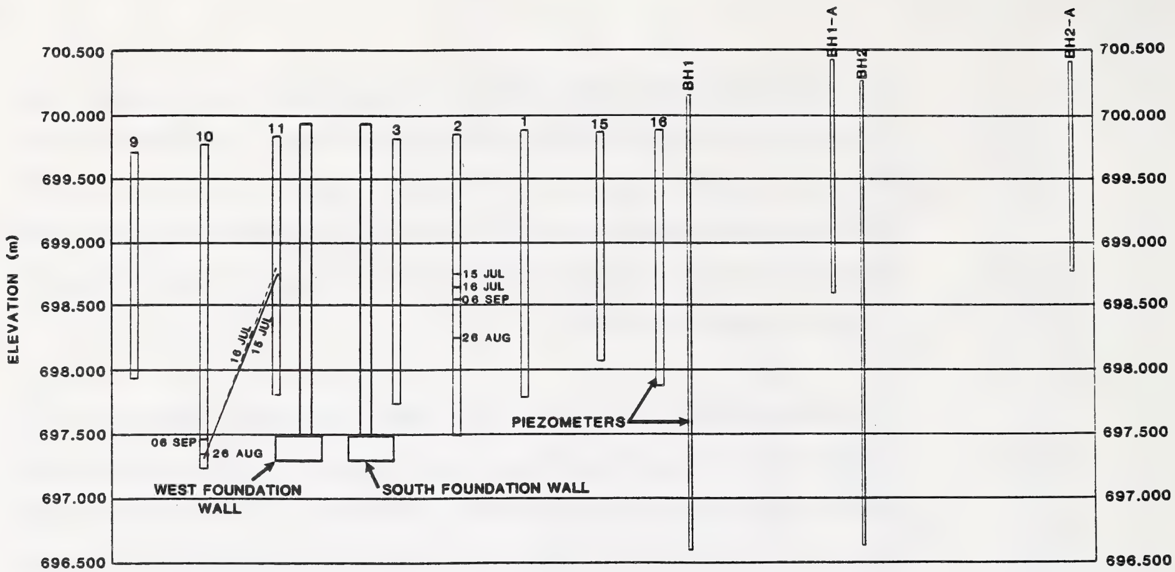
The testing results show that, for lots with good grading and proper roof leader practices, foundation drain response is similar to inflows resulting from cases when roof leaders are connected to storm sewers. The established trend of the roof leader impact indicated by these results was consistent throughout the testing of the various lot characteristics. The exception was the poor grading condition where ponded water had developed for all tests, limiting the additional impact of roof leader discharge.

3.7 Ground Cover Within the Backfill Zone

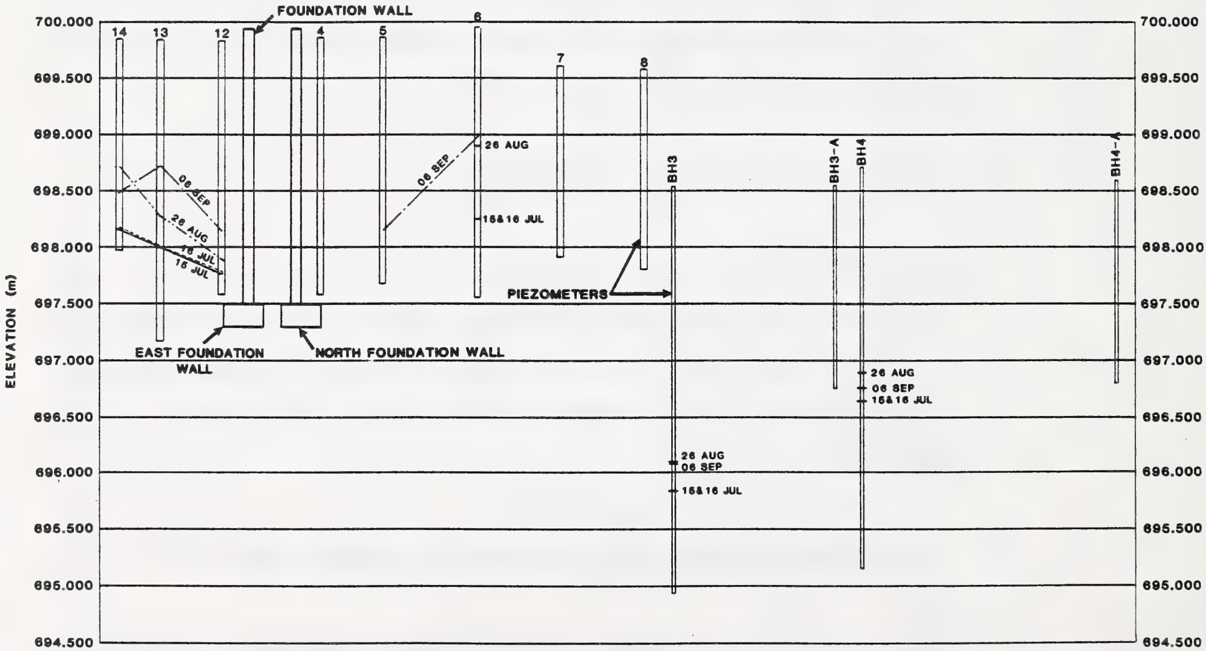
Simulations tested inflow responses with sod and bare ground cover conditions. After comparing and analyzing the sod and bare simulations, no consistent trend or effect on response was established. The variance between the foundation drain response for sod and bare ground cover was not significant.

3.8 Groundwater Response and Antecedent Soil Moisture Condition

Figures 25 and 26 are sample summaries of the groundwater profile during the testing program. The groundwater elevation rose approximately 1 m over the summer, remaining below the footing elevation for all of the testing at the site. Several piezometers around the circumference of the facility, particularly the side yard piezometers, showed fluctuations during simulations. Upon



BACK LOT



FRONT LOT

Figure 25 GROUNDWATER TABLE FLUCTUATIONS FOR ROOF LEADERS AT 1.5m FROM WALL

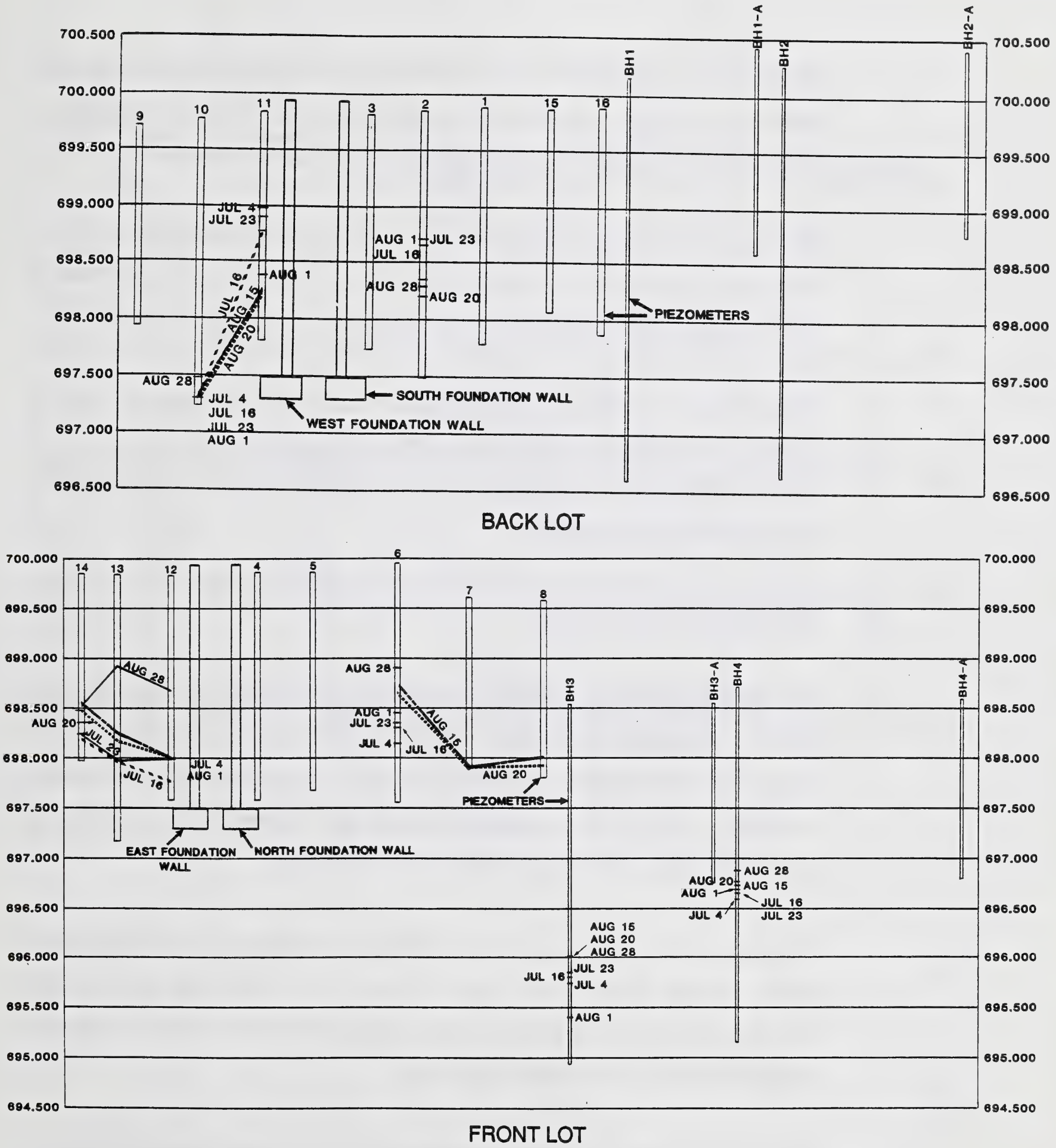


Figure 26 GROUNDWATER TABLE FLUCTUATIONS FOR ROOF LEADERS DISCHARGE @ WALL

analysis of the data, there was no consistent trend between inflow rate and piezometer readings. In some cases, when the water table was the highest, foundation drain flows were significantly less than other simulations.

Further, no trend was established for antecedent soil moisture condition. After three days without precipitation, it was expected that subsequent testing would produce higher inflow rates, however, this result was not observed.

Groundwater responses for the future sand and silt soil types and the natural rainstorm event data will provide additional information for analysis, which may allow the effects of groundwater and antecedent conditions on foundation drain inflow to be established.

3.9 Evaluation of Test Results

The final evaluation to quantify the impacts that various lot characteristics have on foundation drain flows will be carried out on completion of the proposed overall study as outlined in Section 1.0. A preliminary evaluation of Project 1 Clay Till is presented below and Figure 27 is a ranking of foundation drain responses derived from the testing.

The degree of compaction in the backfill zone significantly affects foundation drain response and has the largest impact. Test cases with uncompacted backfill resulted in foundation drain responses ten times greater than any comparable test with compacted backfill.

The limited number of tests conducted on the engineered backfill resulted in significantly less foundation drain response than for other tests. Engineered backfill is a relatively new concept to lot drainage and was tested for comparison purposes. Certain conditions that would impact the cost and

TEST DATE	PEAK RECORDED INFLOW (L/s)	% ENTERING FOUNDATION DRAIN DESIGN STORM	LOT CONFIGURATION											
			COMPACTION			GRADING			GROUND COVER			ROOF LEADER		
			UNCOMP.	COMPACTED	ENG'D	POOR	FLAT	GOOD	BARE	SOD	TYP	WALL	1.5	STORM
AUGUST 28	1.1219	30.56	X				X		X			X		
AUGUST 30	1.0315	27.14	X				X		X				X	
AUGUST 26	0.7005	17.02	X				X		X				X	
JULY 22	0.0429	4.05		X		X			X				X	
JULY 25	0.0415	3.13		X		X			X				X	
JULY 23	0.0346	3.07		X		X			X			X		
JULY 5	0.0854	1.77		X			X				X		X	
JULY 8	0.0679	1.48		X			X				X		X	
JULY 16	0.0672	1.34		X			X		X			X		
JULY 15	0.0562	1.41		X			X		X				X	
JULY 14	0.0384	1.18		X			X		X				X	
AUGUST 1	0.1252	3.13		X				X	X			X		
AUGUST 20	0.0745	2.36		X				X		X		X		
AUGUST 2	0.0233	1.15		X				X	X				X	
AUGUST 3	0.0221	0.97		X				X	X				X	
JULY 30	0.0156	0.84		X				X	X				X	
AUGUST 17	0.0089	0.26		X				X		X			X	
AUGUST 15	0.0275	0.64			X			X		X		X		
AUGUST 10	0.0209	1.23			X			X		X			X	
AUGUST 12	0.0132	0.57			X			X		X			X	

Figure 27 TEST RESULTS IN ASCENDING ORDER OF PERFORMANCE

performance of a full-perimeter engineered backfill system (for instance, below grade window wells) were not achievable within the scope of this work.

However, initial results indicate a potential benefit for lot regrading programs. The practicality of these results should be further evaluated.

The analysis of the clay till tests shows that the grading of backfill and roof leader locations impact foundation drain flow significantly, but to a lesser degree than the level of compaction.

Several of the characteristics that were expected to affect foundation drain response had little impact on inflow for clay till soils. These were storm type, ground cover within the backfill zone, antecedent soil moisture, and groundwater within the backfill zone (based on the static water table being below the drain tile).

It was determined that all lot drainage characteristics act as an integrated system during a storm event. The research findings quantify that proper onsite drainage practices substantially reduced foundation drain flow. A well-graded, older (compacted backfill) sodded lot with 1.5-m roof leader extensions produced 0.07 L/s of foundation drain flow. In comparison, the foundation drain flow for a bare uncompacted site had a response of 0.90 L/s for the same storm event.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Of the variables tested for clay till soil, compaction, grading within the backfill zone, and location of roof leaders had the most significant impacts on foundation drain flow responses during storm events. In particular:

- Inflow response varied from 0.035 L/s for well consolidated fill to 1.120 L/s for loose fill
- Inflow responses for the compacted backfill ranged from 0.035 L/s for good grading in the backfill zone to 0.067 L/s for poor grading conditions
- Inflow ranged from 0.035 L/s for roof leaders discharging 1.5 m from the foundation wall to 0.070 L/s for roof leaders discharging adjacent to the wall.

Storm events, ground cover within the backfill zone, and antecedent moisture conditions had minimal effects on foundation drain response.

4.2 Recommendations

The following recommendations reflect the findings of this research project for clay till soils. The recommendations made are for the design storm (the City of Edmonton 4-hour, 5 year event) used in the research:

1. Compaction of backfill for new construction is recommended. Because of costs, it is impractical to specify the degree of compaction or soils testing to define compaction; however, compactive effort should be specified. The compaction specification should state that backfill material should be placed to a flat grade condition and compacted with a hydraulic tamper or equivalent. Additional fill should then be

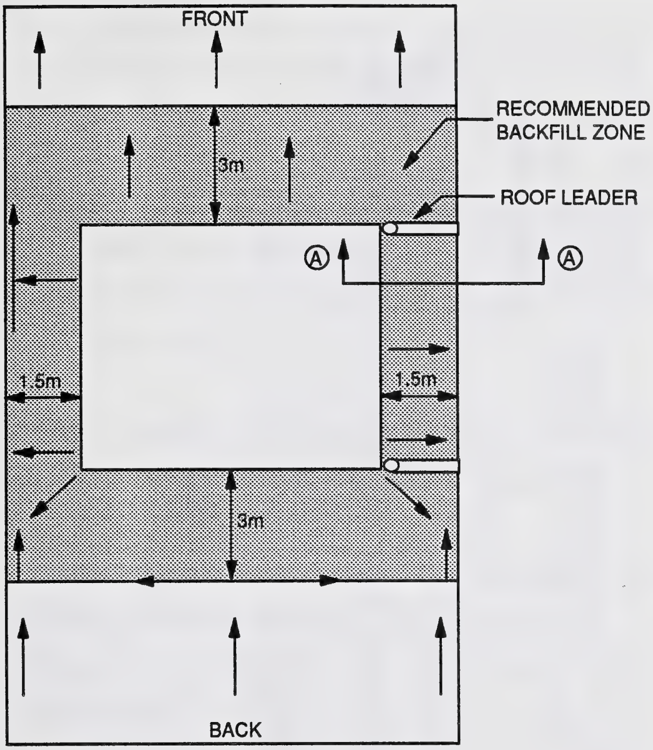
placed, graded and compacted to yield a positive grade of 5 to 10 percent extending at least the width of the backfill zone as illustrated in Figure 28. (Concurrent foundation wall research at the research facility by the University of Alberta department of Civil Engineering cautions against over-compaction, since large bridging forces against the upper portion of the foundation wall could result The moderate degree of compaction tested in this project falls within the "safe" compaction limits stipulated by the University's report).

2. It is recommended that the backfill zone be graded to a minimum of 5 percent away from the foundation. The backfill zone would be defined as a 1.5-m width (minimum) at the side yards, 3.0-m in the back and front yards. Where property lines permit, side yard backfill zones should be increased to 3.0-m.

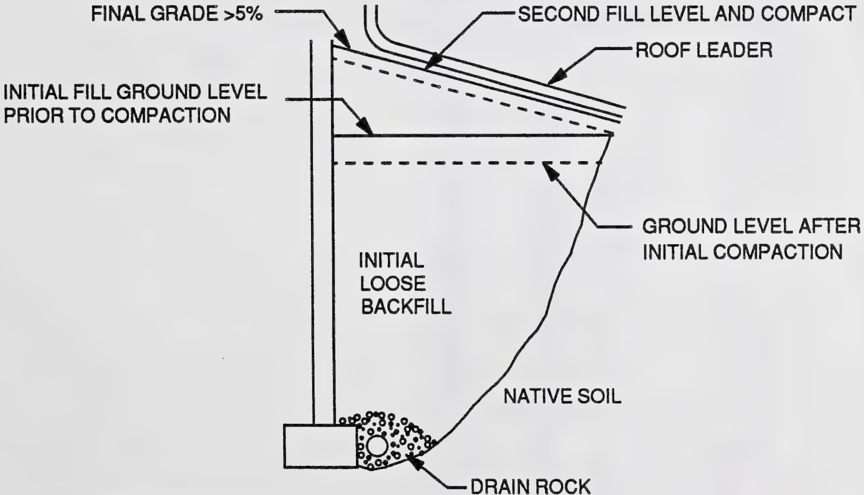
3. The use of saturated and/or frozen material as backfill should not be permitted. Suitable native, loose, onsite material or imported backfill material should be specified.

4. Roof leaders should have an attached 1.5-m extension (or longer, to suit the width of the backfill zone). The extensions should be attached with a permanent hinge or equivalent to ensure proper roof leader practices.

5. The foundation drain flow values for clay till soil derived from the research represent a range of lot drainage characteristics and a single design value is not suggested. The range of recommended values for the various lot characteristics is summarized in Figure 29. Based on foundation drain responses for the design storm, the following design values are recommended:



RECOMMENDED BACKFILL ZONE
SLOPE - MINIMUM 5%


FINAL GRADE >5%
SECOND FILL LEVEL AND COMPACT
ROOF LEADER
INITIAL FILL GROUND LEVEL PRIOR TO COMPACTION
GROUND LEVEL AFTER INITIAL COMPACTION
INITIAL LOOSE BACKFILL
NATIVE SOIL
DRAIN ROCK

SECTION A-A

Figure 28 RECOMMENDED GRADING AND BACKFILL PROCEDURE

FOUNDATION DRAIN DESIGN FLOWRATES FOR CLAY TILL SOILS

LOT CHARACTERISTICS							DESIGN VALUE BASED ON 4 HOUR - 5 YEAR DESIGN STORM (L/s)
COMPACTION		GRADING IN BACKFILL ZONE			ROOF LEADER LOCATION		
UNCOMP.	COMPACT.	POOR	FLAT	GOOD	@WALL	1.5m EXT.	
X		X	X	X	X	X	1.3
	X	X			X	X	0.08
	X		X		X	X	0.08
	X			X	X		0.08
	X			X		X	0.03
ENGINEERED BACKFILL PRACTICE - AS PER TRIALS							0.03

Figure 29 FOUNDATION DRAIN DESIGN FLOWRATES FOR CLAY TILL SOIL

- For older subdivisions with settled backfill zones and a variety of lot characteristics (assuming the majority of lots have average-to-good drainage practices), the design peak inflow recommended is 0.08 L/s/house.
- For new subdivisions with uncompacted backfill, the design peak inflow recommended is 1.3 L/s/house assuming the majority of homes are not yet landscaped and/or are under construction.

6. Further evaluation of engineered backfill as a retrofit practice should be carried out on a different soil type and a variety of lot types.

7. The conventional construction practice of covering the drain tile with 150 mm of crushed stone was used at the test site and the system performed well; therefore, changes to foundation drains are not recommended.

8. It is recommended that foundation drain flow be discharged to surface, using sump pump systems as documented in the Sump Pump Study, 1991.

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APPENDIX A

SITE DESCRIPTION AND RESEARCH FACILITY DESIGN

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1.0 SITE DESCRIPTION

1.1 Site Selection and Location

Strathcona County provided the site for the test facility. The criteria in selecting the site incorporated the requirements for the intended research and other considerations related to the long-term use of the building. Sites were evaluated based on:

- Access to a sufficient water supply for rainfall simulations (fire hydrant)
- Proximity to electrical service
- Adequate offsite drainage
- Proximity to adjacent properties that could be negatively affected by ongoing site testing and related construction
- Accessibility for both summer and winter testing.

The site selected for the research facility is on the northeast corner of the Strathcona County Water Reservoir Site, 17th Street and 92nd Avenue, Strathcona County. (See Figure A1.)

1.2 General Site Description

The site is relatively level with a gentle slope downward to the north (approximately 4.3 percent). There is natural drainage along the north of the site and a constructed roadway ditch along the east (17th Street). Buried water lines and overhead high voltage power bisect the northern portion of the site and additional water lines are adjacent to the east boundary. The site has gravelled access roads on both the south and west boundaries.

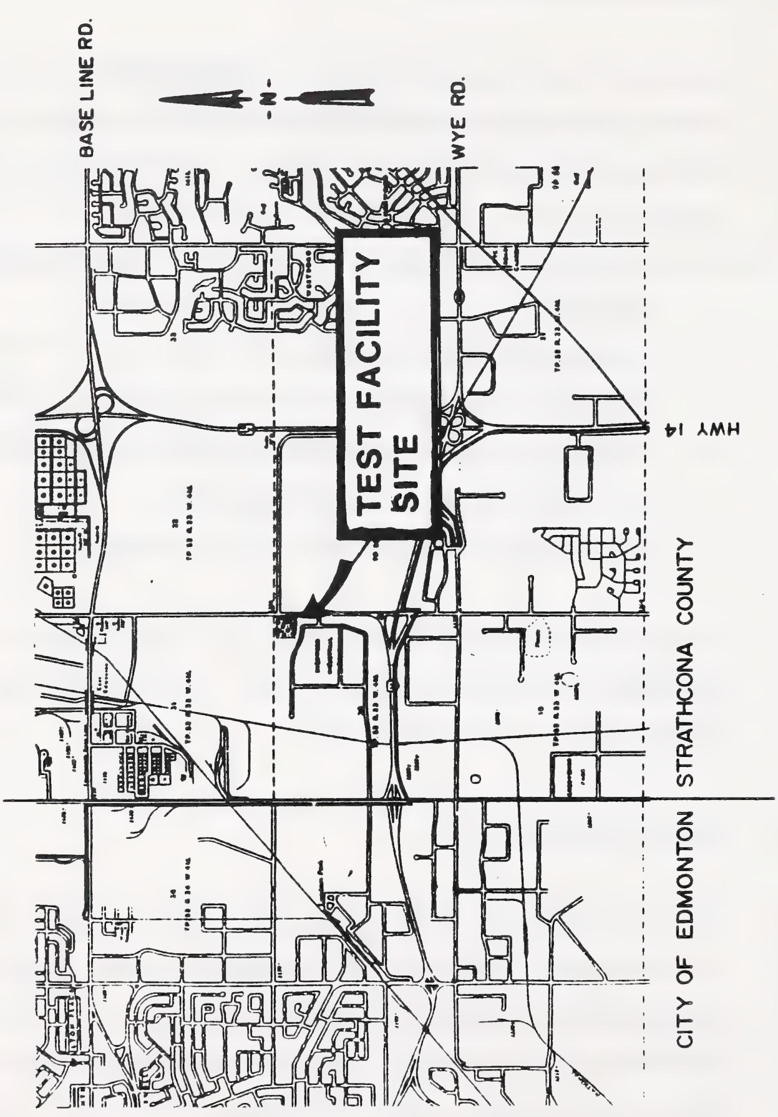

Figure A1 LOCATION PLAN

2.0 RESEARCH FACILITY DESIGN

The test facility was intended to be typical of residential construction in Alberta. To meet this project objective, industry standards were followed with respect to dimensions, materials, and construction. The research facility models an average sized bungalow in dimensions, with a floor area of 99 m^2 (1,065.7 ft^2). The facility design incorporates two specific research-related components, which are the foundation drainage system and instrumentation. The foundation drainage system consists of two sumps, geomembrane and cutoff walls, valving, and clean-out/inspection access piping. The instrumentation includes the data loggers and water level recorders.

2.1 Design Details - Foundation Drainage

The foundation drainage system is specifically designed for a variety of foundation drain research projects. The facility can be operated as a single site, or separated into two zones (split site), to increase the rate of testing, if desired. It also allows for an ongoing comparison of results. To provide this capability, a second sump, special valving, and seepage cutoff footings were constructed. To operate as a split site, two geomembrane cutoff curtains were installed at two diagonally opposite corners, attached to the foundation wall and cutoff footings. Appropriate valve settings will be made, and both pumps will be utilized. Clean-outs on the foundation drains are located at each corner of the building and provide access points for camera inspection and system maintenance.

The research facility design features for the field testing of lot drainage characteristics are presented in Figures A2 through A8. The following descriptions provide additional information for each figure:

Figure A2: Lot Drainage Research Facility

The lot provides back-to-front drainage, which is the predominant lot drainage pattern in newer subdivisions. With the valving of the foundation drain and the geomembrane, the foundation drain response of the back-yard may be separated from the front-yard. The simulated rainfall events applied water uniformly over the site, including the roof area.

Figure A3: Piezometer Locations

The piezometers were installed to monitor groundwater fluctuations within the backfill zone and the undisturbed soil. Front, back, and side yards are monitored.

Figure A4: Foundation Drain and Sump Plan

As previously described, the site may be split to measure back-yard and front-yard foundation drain flow separately. The back-yard foundation drain flow may be directed to Sump 1 and the front-yard flows to Sump 2. Either sump may be used if the test is for a single sump pump system configuration.

Two sump volumes were tested:

Sump 1 was designated the large sump and has the following dimensions:

Area 0.980 x 0.976 = 0.957 m^2
Total depth (top of floor to base) ≈ 1.0 m
Total volume = 0.96 m^3
Active volume (base to invert of inflow) = 0.42 m^3

Sump 2 was designated the small sump and the volume was adjusted by fitting rigid insulation to the sump walls. The dimensions of Sump 2 used during the field testing were:

Area .670 x .976 = 0.486 m^2
Total depth ≈ 1.0 m
Total volume = 0.49 m^3
Active volume 0.21 m^3

Figure A5: Piezometer Asbuilt

The piezometers were installed to monitor groundwater fluctuations. As shown on Figure A3, a total of 24 piezometers are installed. Figure A5 details the three piezometers on the back-yard portion of the site, which is typical for all four sites. Piezometers 3, 2, and 1 monitor groundwater fluctuations immediately over the foundation drain, at the transition of backfill and native soil and within native soil, respectively.

Figure A6: Foundation Drain and Sump Pump Detail

The foundation drain flows into the sump (for both Sump 1 and 2) and discharges to surface by automatic pump. The sump water elevation is monitored by a level recorder, thus recording inflow. The pump is monitored by an on/off sensor that records running time, which allows for discharge calculations, total pump running time, and cycle time.

Figure A7: Schematic of Site Instrumentation

The site of the research facility has instrumentation that automatically records data 24 hours a day. Natural rainfall events are measured by a Rimco raingauge, which is a tipping bucket type. The number of tips is recorded to the data logger, which is downloaded into a computer and analyzed using the manufacturer's software. The

Rimco Raingauge records were checked on a weekly basis.

This allowed for natural rainfall events to be separated from test simulations when the events overlapped.

Groundwater fluctuations were measured by 16 piezometers grouped at various distances around the foundation. Three piezometers monitoring the backfill zone in the back yard and three similarly in the front yard were furnished with float and counterweight assemblies. The float elevations generated potentiometer readings that were recorded on Data Logger 01. Data Logger 01 recorded readings at 15-min intervals for the six piezometers equipped with the device. The remaining 10 piezometers around the foundation, two at each lot corner, were read manually at the start of each test, at 2-hour intervals during the test, and at the end of each test.

The sump water level in each sump was monitored by float and counterweight devices connected to Data Logger 02. The sump pump was equipped with on/off sensors that were also connected to Data Logger 02. The water level in the sumps was recorded every 15-min and also at pump start and stop. The pump running time was recorded to 1 sec accuracy.

Figure A8: Pump Curve - Goulds Model 3871

The field tests in which foundation drain response was the indicator of effectiveness used the Goulds Model 3871 pump. A single pump model was selected for these tests to limit the variables in foundation drain flow analysis.

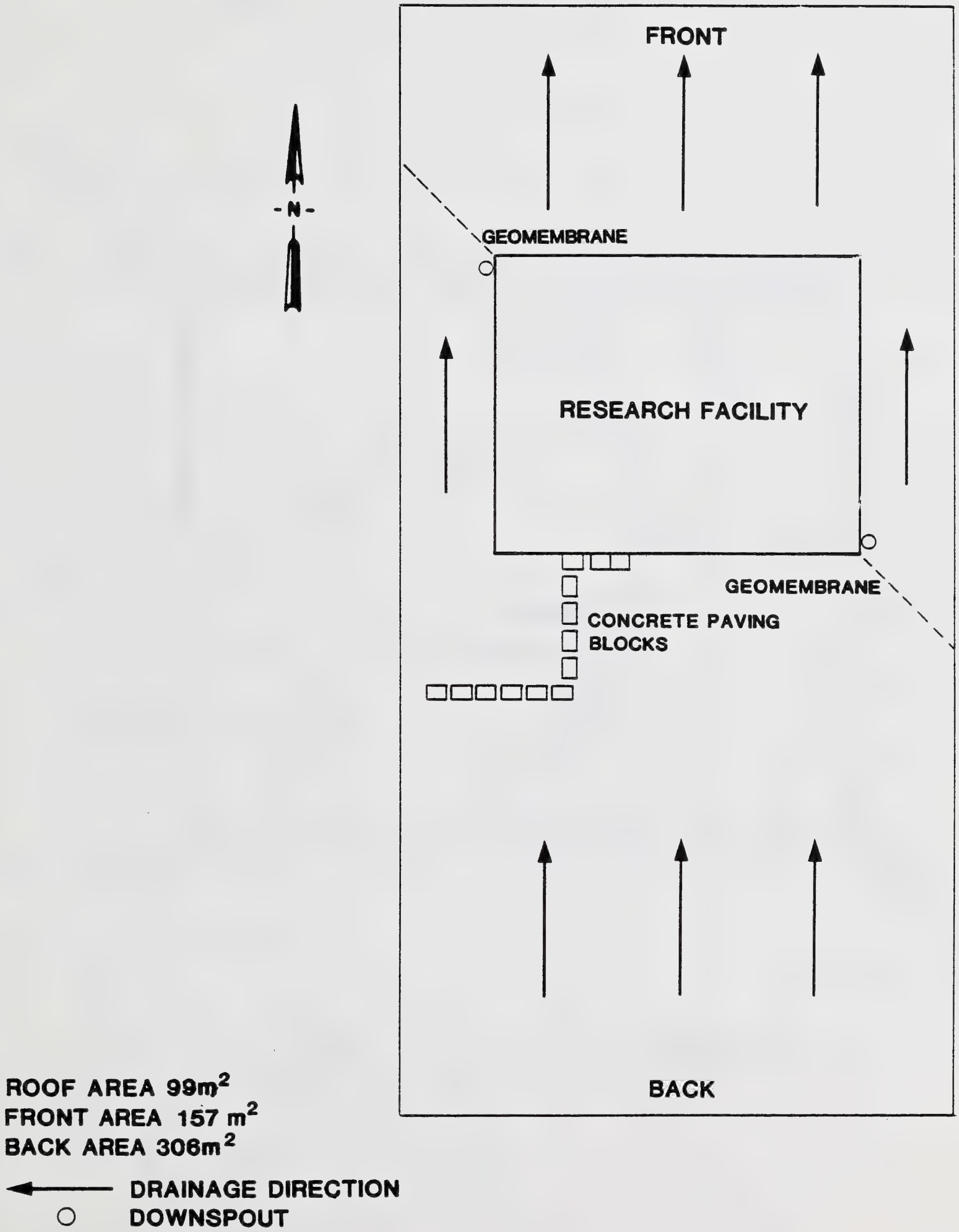

Figure A2 LOT DRAINAGE
RESEARCH FACILITY
LOT PLAN

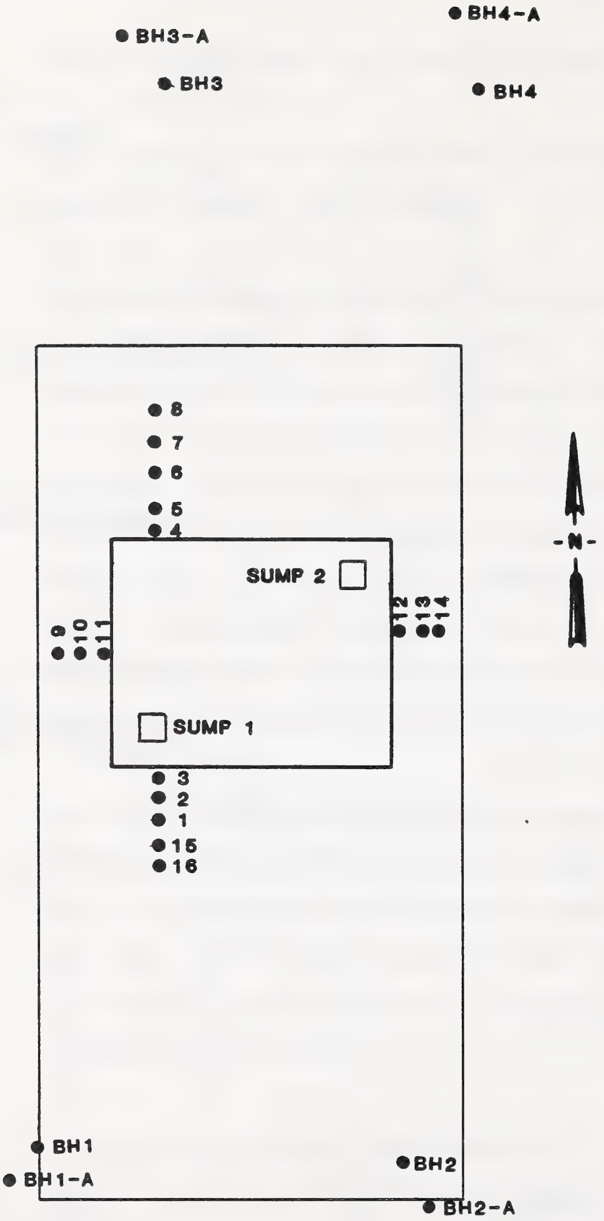

Figure A3 PIEZOMETER LOCATIONS

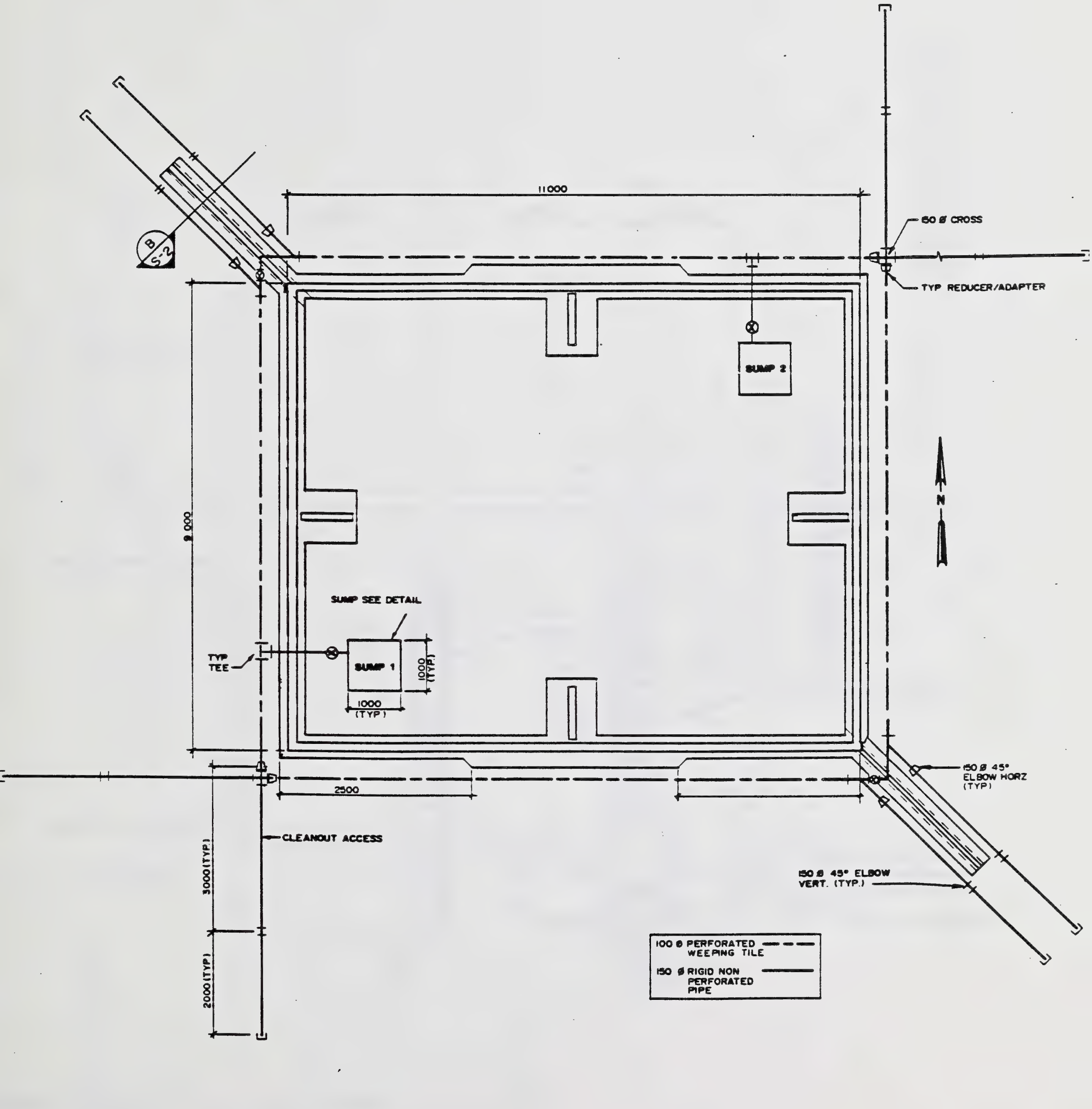

Figure A4 FOUNDATION DRAIN AND SUMP PLAN

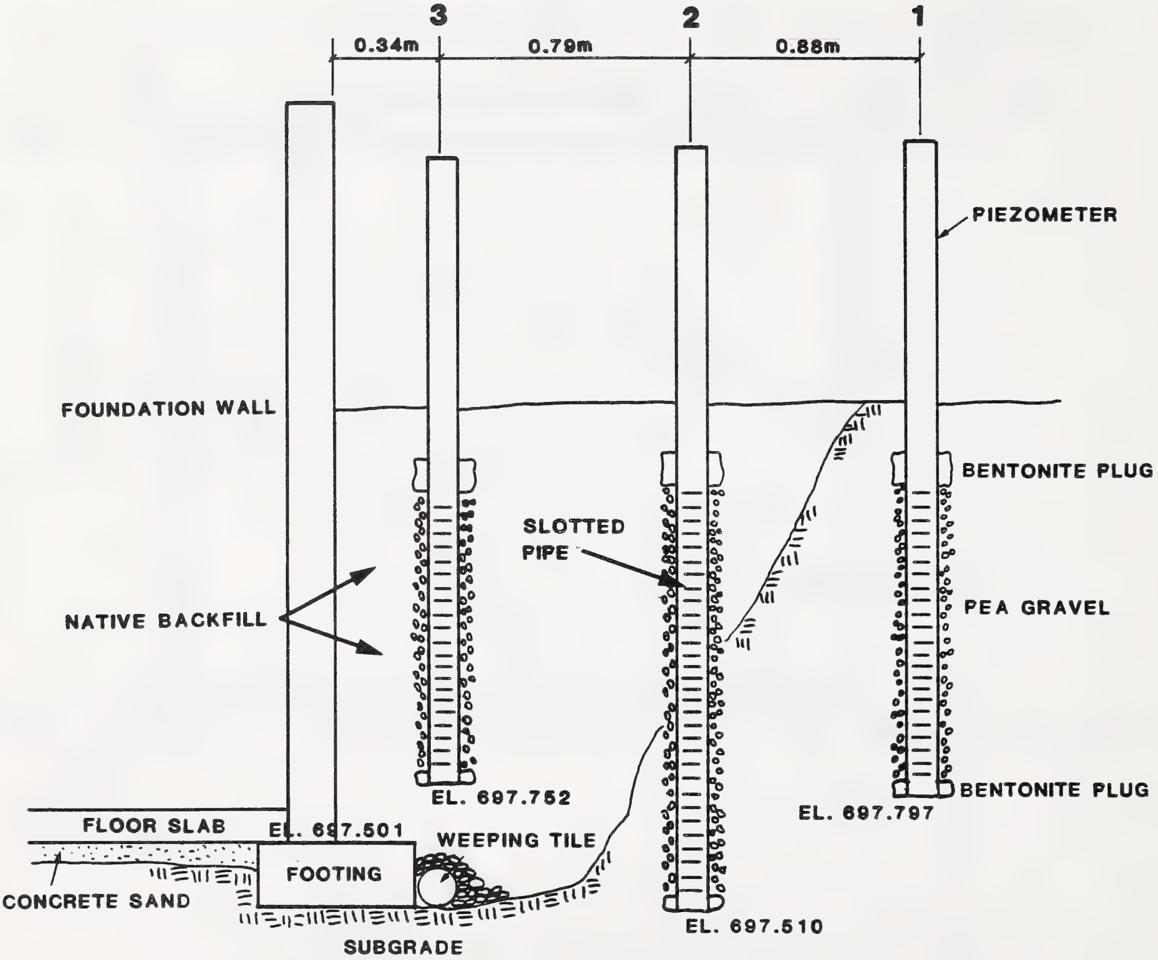

Figure A5 PIEZOMETER AS-BUILT FOR BACK YARD - FRONT YARD PIEZOMETER INSTALLATION IS THE REVERSE

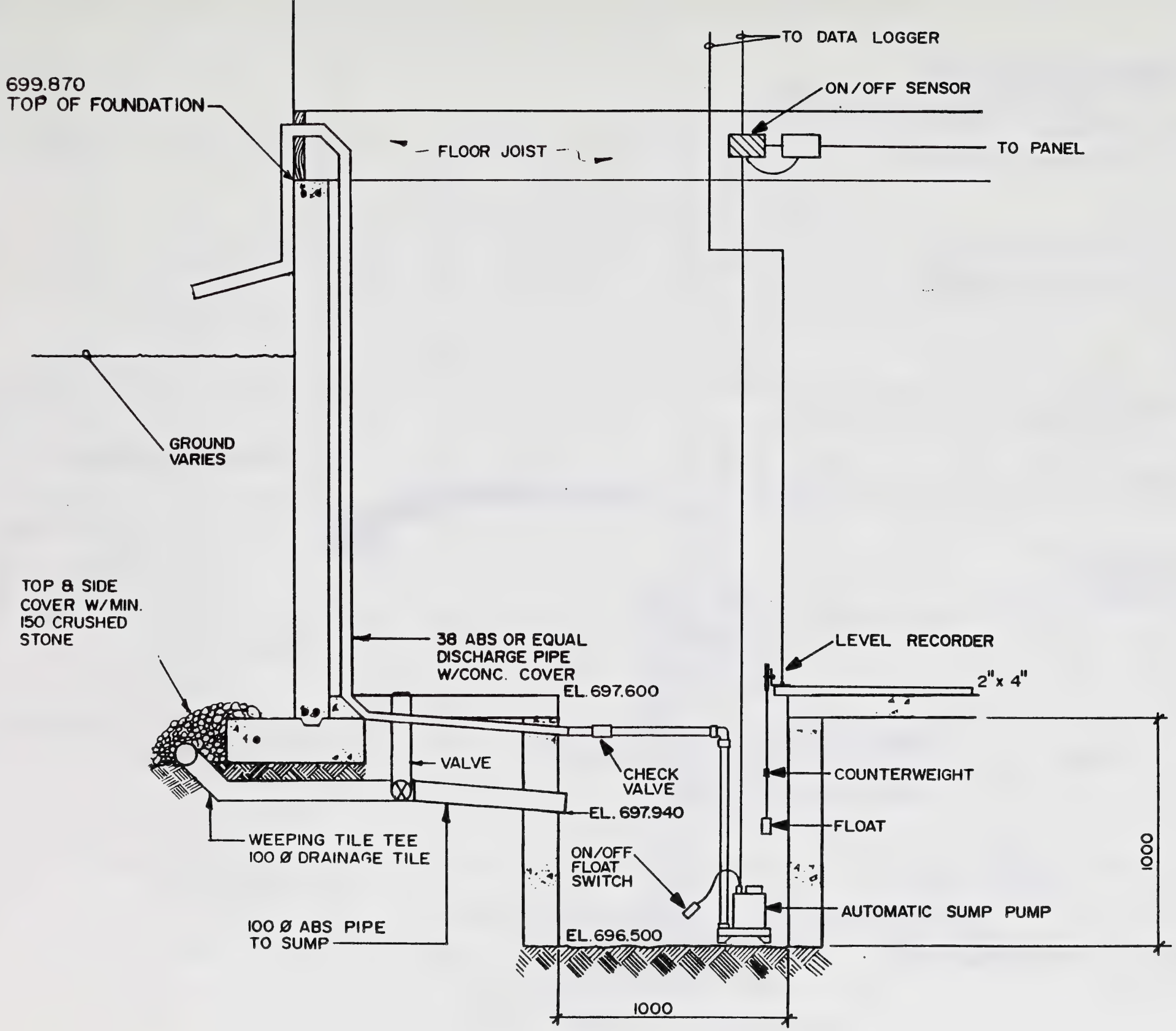

Figure A6 FOUNDATION DRAIN AND SUMP DETAIL

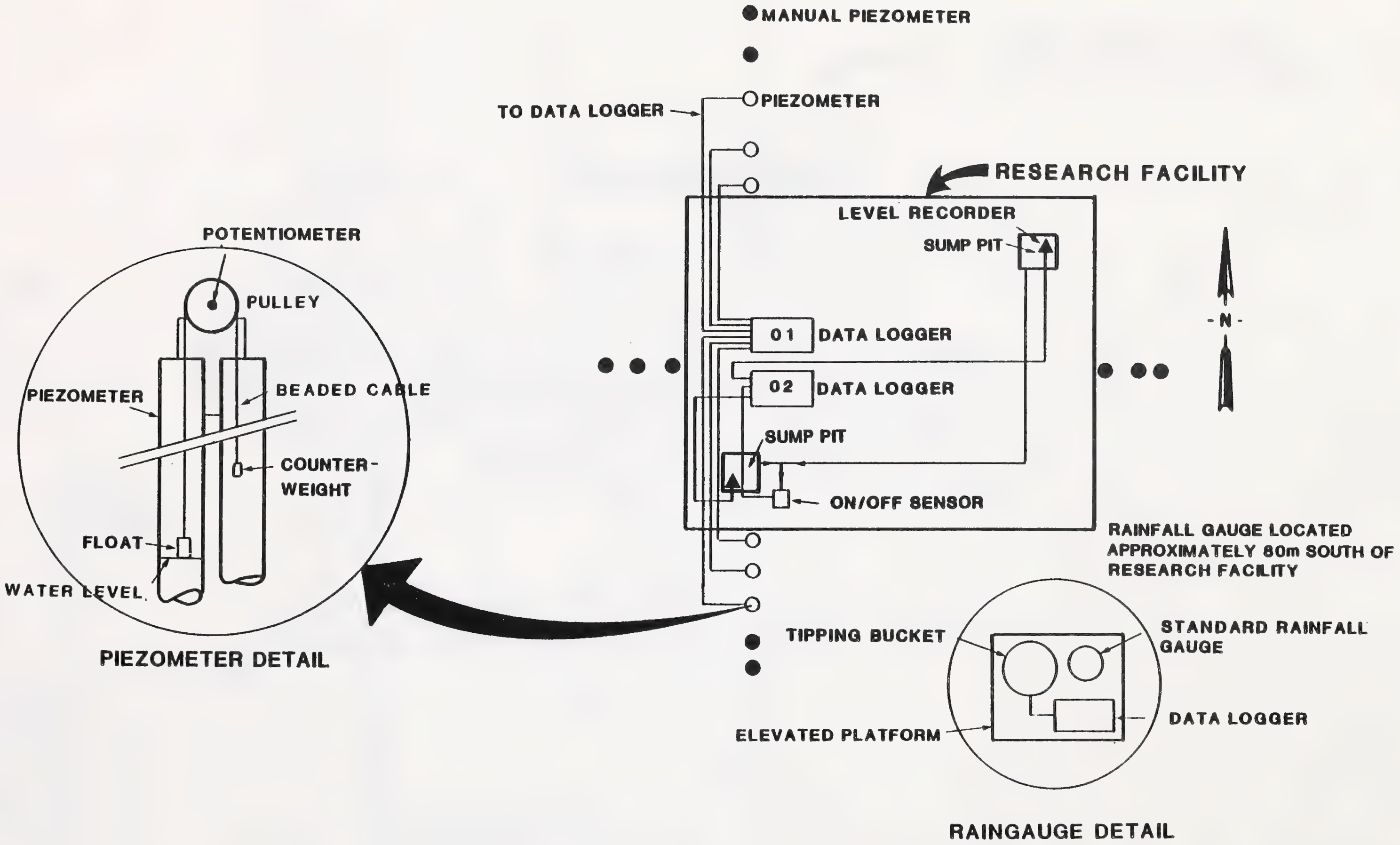

Figure A7 SCHEMATIC
SITE INSTRUMENTATION

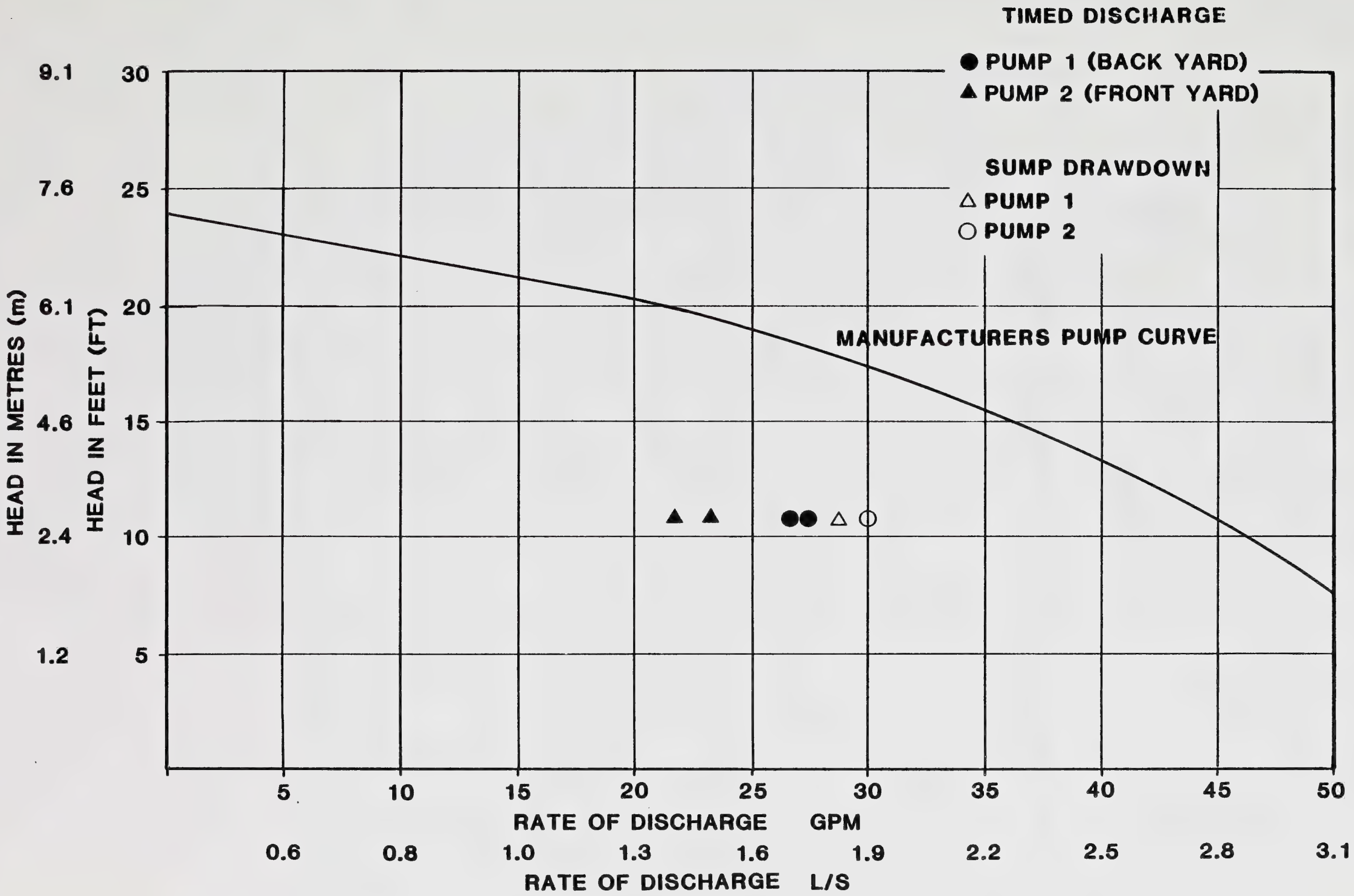

Figure A8 GOULDS PUMP CURVE MODEL 3871

APPENDIX B

A SAMPLE OF THE TESTING PROGRAM RESULTS

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1.0 TEST RESULTS

This section of the Appendix presents the monitored results of the field testing program. Analysis of the tests is presented in Section 3.0 of the report.

The amount of data obtained is significant and guidance through the material is provided on the following figures and described below:

Figure B1: Summary of Simulations

This summary sheet presents a snapshot of each test. The summary sheet may be used as both a summary for comparisons and an index of the detailed test results.

Figure B2 through B8: Lot Grading

These figures show the lot configuration and grading for the testing program. All elevations and grades are as-built for the respective test.

Figure B9: Engineered Backfill

Engineered backfill for this project is an impermeable geotextile placed over the compacted backfill.

Figure B10: Typical Ground Cover

This figure shows the ground cover condition at the research site that this project defined as typical.

Figure B11: Roof Leader Location

Three roof leader locations were tested for each lot grading configuration. The discharge of the roof leaders was simulated by connecting hoses with appropriate flowrate, to the roof leaders. For the discharge to storm test, the hose was turned off.

Figure B12: Time to Peak

Figure B1, Summary of Simulations and similar summary sheets contain two columns, one labelled Time to Peak from Start and the other, Time to Peak from Peak. Both calculations are important in analyzing foundation drain response.

Figure B13 through B17:

These figures are summaries of simulations by backfill zone condition and provide lot characteristic information. The terminology used in the title of the figures describes the backfill zone condition. For example, Compacted Good is compacted backfill with good grading around the foundation.

1.1 Individual Test Results

The results for sample tests are presented in the following sequence of information sheets depending on the test condition. Based on the test carried out, portions of or all of the following data sheets are presented for the individual test dates.

Test Information

This is a two-sheet-form with the following information: weather, site constraints, site measurements, site checks, comments, and sketch of the configuration.

Piezometer Measurement Record

This is the record of the manually read piezometers.

Inflow/Intensity Figure

This figure presents the lot characteristics in the top right corner, the rainfall hyetograph in the top left corner, and the foundation drain response. Test days could have three inflow/intensity figures: Total-Lot, Back-Lot and Front-Lot. The back-lot, front-lot monitoring was done using a split-lot drainage configuration.

Piezometer

The piezometer charts present the groundwater levels relative to the top of the footing (foundation drain) for the piezometers equipped with water level recorders. The maximum level is the maximum groundwater fluctuation during the test.

SUMMARY OF SIMULATIONS

TEST DATE	STORM	START TIME	VOLUME APPLIED (L)	INTENSITY APPLIED (mm/hr)	PEAK RECORDED INFLOW (L/s)	% ENTERING FOUNDATION DRAIN EXCLUDING NATURAL RAINFALL				TIME TO PEAK		COMPACTION	GRADING	GROUND COVER	ROOF LEADER LOCATION
						FRONT	BACK	TOTAL	BASEFLOW(EXCL.) TOTAL	Tp (min)	Pp (min)				
24-May	4-hr/5-yr	10:00	22040	40.38	0.0348			4.20				COMPACTED	FLAT	SOD	1.5m
27-May	4-hr/5-yr	09:30	22040	40.38	0.0366			5.00				COMPACTED	FLAT	SOD	1.5m
29-May	4-hr/5-yr	09:40	22040	40.38	0.0120			2.70				COMPACTED	FLAT	SOD	1.5m
31-May	4-hr/50-yr	12:15	39720	67.31	0.0590			1.70				COMPACTED	FLAT	SOD	1.5m
04-Jun	4-hr/50-yr	09:15	39720	67.31	0.0550			2.10				COMPACTED	FLAT	SOD	1.5m
10-Jun	4-hr/5-yr	10:45	22040	40.38	0.0179			1.70				COMPACTED	FLAT	SOD	WALL
20-Jun	24-hr/5-yr	03:00	35180	12.45	0.0517			6.28		400.46	40.46	COMPACTED	FLAT	SOD	1.5m
25-Jun	24-hr/5-yr	03:00	35180	12.45	0.0444			5.01		411.62	51.62	COMPACTED	FLAT	SOD	1.5m
27-Jun	24-hr/25-yr	03:00	54910	18.54	0.0845			5.21		417.20	57.20	COMPACTED	FLAT	SOD	1.5m
30-Jun	24-hr/25-yr	03:00	52100	18.54	0.0530			2.43		419.50	59.50	COMPACTED	FLAT	SOD	1.5m
02-Jul	4-hr/5-yr	12:30	22040	40.38	0.0739	1.58	2.53	2.18		96.49	21.49	COMPACTED	FLAT	SOD	1.5m
03-Jul	4-hr/5-yr	09:30	22040	40.38	0.0796	1.65	2.45	2.16		85.36	10.36	COMPACTED	FLAT	SOD	1.5m
04-Jul	4-hr/5-yr	10:30	22040	40.38	0.0974			1.90	1.56	81.64	6.64	COMPACTED	FLAT	SOD	STORM
05-Jul	4-hr/5-yr	11:30	22040	40.38	0.0854			2.11	1.77	76.08	1.08	COMPACTED	FLAT	TYPICAL	1.5m
08-Jul	4-hr/5-yr	09:45	22040	40.38	0.0679	1.54	1.97	1.81	1.48	90.92	15.92	COMPACTED	FLAT	TYPICAL	1.5m
10-Jul	24-hr/5-yr	03:00	35180	12.45	0.0274			1.63	1.00	400.46	40.46	COMPACTED	FLAT	TYPICAL	1.5m
14-Jul	4-hr/5-yr	12:00	22040	40.38	0.0384			1.51	1.18	103.91	28.91	COMPACTED	FLAT	BARE	1.5m
15-Jul	4-hr/5-yr	11:00	22040	40.38	0.0562	1.70	1.77	1.74	1.41	92.78	17.78	COMPACTED	FLAT	BARE	1.5m
16-Jul	4-hr/5-yr	08:10	22040	40.38	0.0672	0.83	2.16	1.67	1.34	89.07	14.07	COMPACTED	FLAT	BARE	WALL
18-Jul	4-hr/5-yr	08:00	22040	40.38	0.0305	1.07	1.06	1.07	0.73	111.34	36.34	COMPACTED	FLAT	BARE	STORM
22-Jul	4-hr/5-yr	15:25	22040	40.38	0.0429	2.43	5.53	4.39	4.05	115.05	40.05	COMPACTED	POOR	BARE	1.5m
23-Jul	4-hr/5-yr	09:30	22040	40.38	0.0346	2.50	3.94	3.41	3.07	79.79	4.79	COMPACTED	POOR	BARE	WALL
24-Jul	4-hr/5-yr	10:15	22040	40.38	0.0342	2.56	3.97	3.45	3.12	102.06	27.06	COMPACTED	POOR	BARE	STORM
25-Jul	4-hr/5-yr	14:30	22040	40.38	0.0415	3.22	3.61	3.47	3.13	92.78	17.78	COMPACTED	POOR	BARE	1.5m
30-Jul	4-hr/5-yr	11:00	22040	40.38	0.0156	0.39	1.63	1.18	0.84	105.77	30.77	COMPACTED	GOOD	BARE	1.5m
31-Jul	4-hr/5-yr	11:30	22040	40.38	0.0206	1.36	1.82	1.65	1.31	98.35	23.35	COMPACTED	GOOD	BARE	STORM
01-Aug	4-hr/5-yr	10:10	22040	40.38	0.1252	1.53	4.56	3.44	3.13	68.65	-6.35	COMPACTED	GOOD	BARE	WALL
02-Aug	4-hr/5-yr	10:00	22040	40.38	0.0233	1.34	1.57	1.49	1.15	89.07	14.07	COMPACTED	GOOD	BARE	1.5m
03-Aug	4-hr/5-yr	10:10	22040	40.38	0.0221	1.83	1.00	1.31	0.97	92.78	17.78	COMPACTED	GOOD	BARE	1.5m
10-Aug	4-hr/5-yr	13:05	22040	40.38	0.0209	0.30	2.29	1.56	1.23	100.20	25.20	ENGINEERED	GOOD	SOD	1.5m

Figure B1 SUMMARY OF SIMULATIONS

SUMMARY OF SIMULATIONS

TEST DATE	STORM	START TIME	VOLUME APPLIED (L)	INTENSITY APPLIED (mm/hr)	PEAK RECORDED INFLOW (L/s)	% ENTERING FOUNDATION DRAIN EXCLUDING NATURAL RAINFALL				TIME TO PEAK		COMPACTION	GRADING	GROUND COVER	ROOF LEADER LOCATION
						FRONT	BACK	TOTAL	BASEFLOW(EXCL.) TOTAL	Tp (min)	Pp (min)				
12-Aug	4-hr/5-yr	09:05	22040	40.38	0.0132	0.41	1.19	0.90	0.57			ENGINEERED	GOOD	SOD	1.5m
14-Aug	4-hr/5-yr	10:55	22040	40.38	0.0123	0.50	1.09	0.87	0.54	103.91	28.91	ENGINEERED	GOOD	SOD	STORM
15-Aug	4-hr/5-yr	10:35	22040	40.38	0.0275	0.41	1.31	0.98	0.64	87.21	12.21	ENGINEERED	GOOD	SOD	WALL
17-Aug	4-hr/5-yr	14:50	22040	40.38	0.0089	0.69	0.54	0.60	0.26			COMPACTED	GOOD	SOD	1.5m
19-Aug	4-hr/5-yr	09:40	22040	40.38	0.0150	0.72	0.85	0.80	0.47	102.60	27.60	COMPACTED	GOOD	SOD	STORM
20-Aug	4-hr/5-yr	11:15	22040	40.38	0.0745	1.23	3.54	2.69	2.36	92.78	17.78	COMPACTED	GOOD	SOD	WALL
26-Aug	4-hr/5-yr	13:20	22040	40.38	0.7005	16.87	17.64	17.36	17.02	94.63	19.63	UNCOMPACTED	FLAT	BARE	1.5m
27-Aug	4-hr/5-yr	10:45	22040	40.38	0.4457	10.50	13.59	12.46	12.12	111.34	36.34	UNCOMPACTED	FLAT	BARE	STORM
28-Aug	4-hr/5-yr	09:45	22040	40.38	1.1219	46.02	22.06	30.87	30.56	81.64	6.64	UNCOMPACTED	FLAT	BARE	WALL
30-Aug	4-hr/5-yr	09:50	22040	40.38	1.0315	26.92	27.81	27.48	27.14	81.86	6.86	UNCOMPACTED	FLAT	BARE	1.5m
03-Sep	4-hr/5-yr	09:40	22040	40.38	0.8777			28.43	28.10	90.92	15.92	UNCOMPACTED	FLAT	BARE	1.5m
05-Sep	4-hr/5-yr	09:40	22040	40.38	2.7299			156.16	155.83	83.50	8.50	UNCOMPACTED	FLAT	BARE	1.5m
06-Sep	4-hr/5-yr	12:30	22040	40.38	2.3902			131.16	130.82	76.08	1.08	UNCOMPACTED	FLAT	BARE	1.5m
07-Sep	4-hr/5-yr	11:15	22040	40.38	2.7484			73.55	73.22	96.49	21.49	UNCOMPACTED	FLAT	BARE	1.5m

Figure B1 SUMMARY OF SIMULATIONS

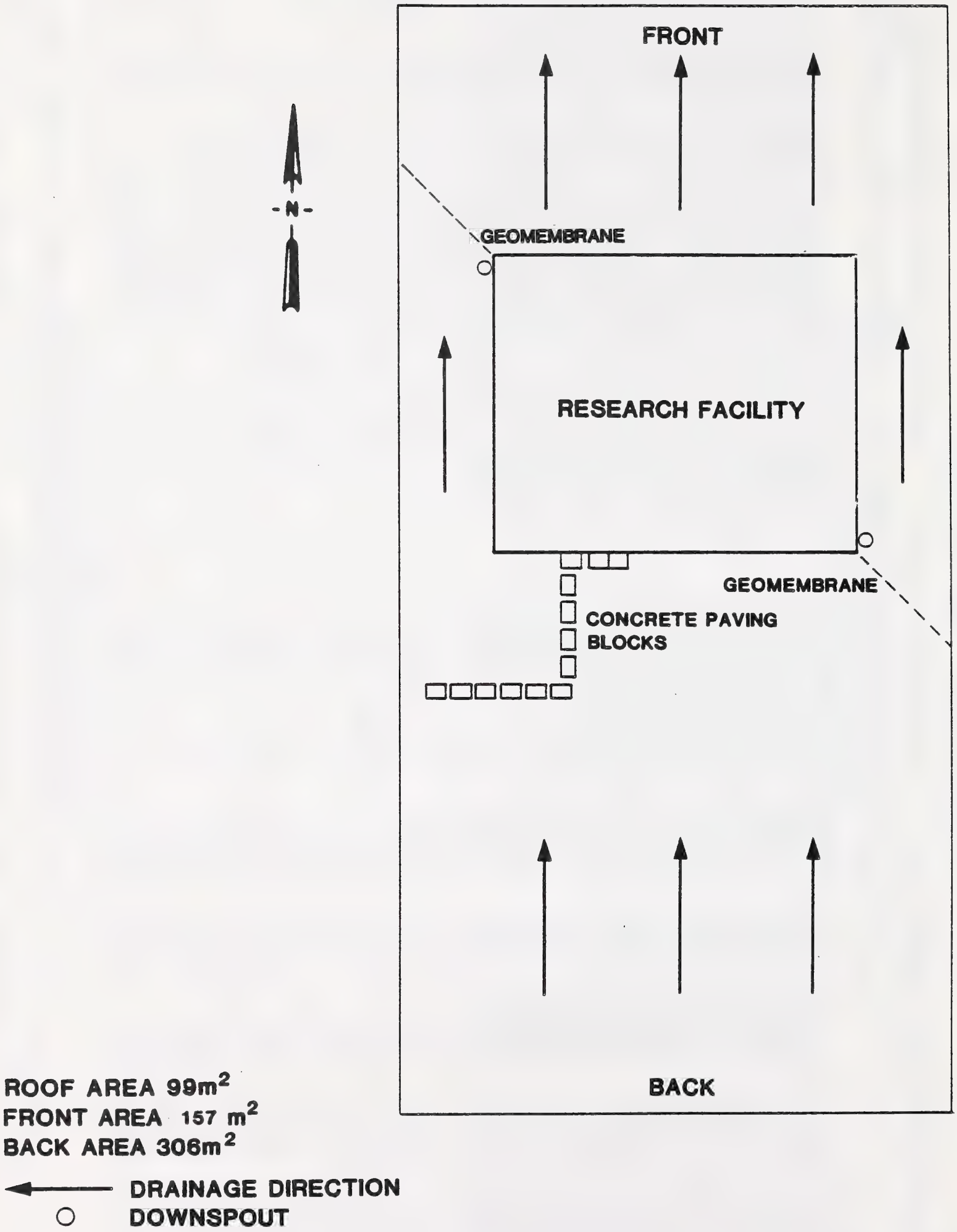


Figure B2 LOT DRAINAGE
RESEARCH FACILITY
LOT PLAN

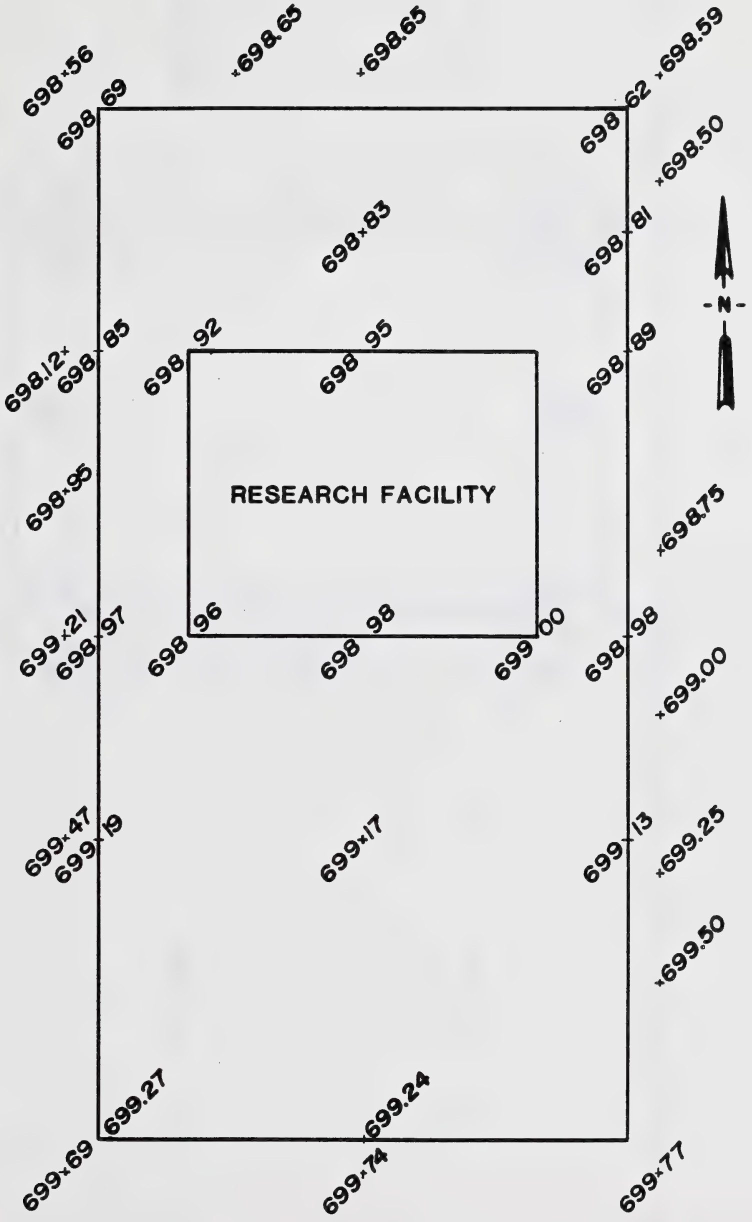


Figure B3 LOT ELEVATIONS

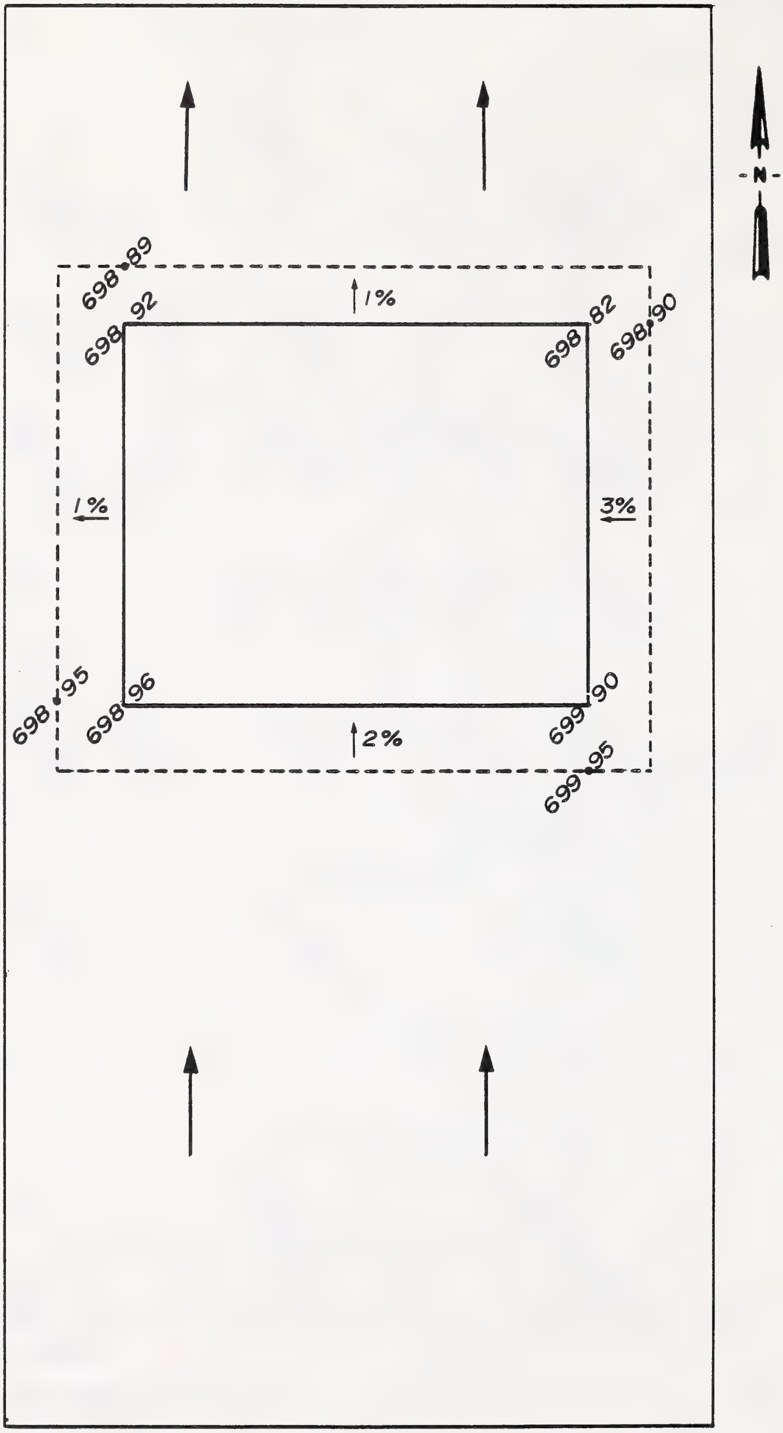


Figure **B4** COMPACTED FLAT

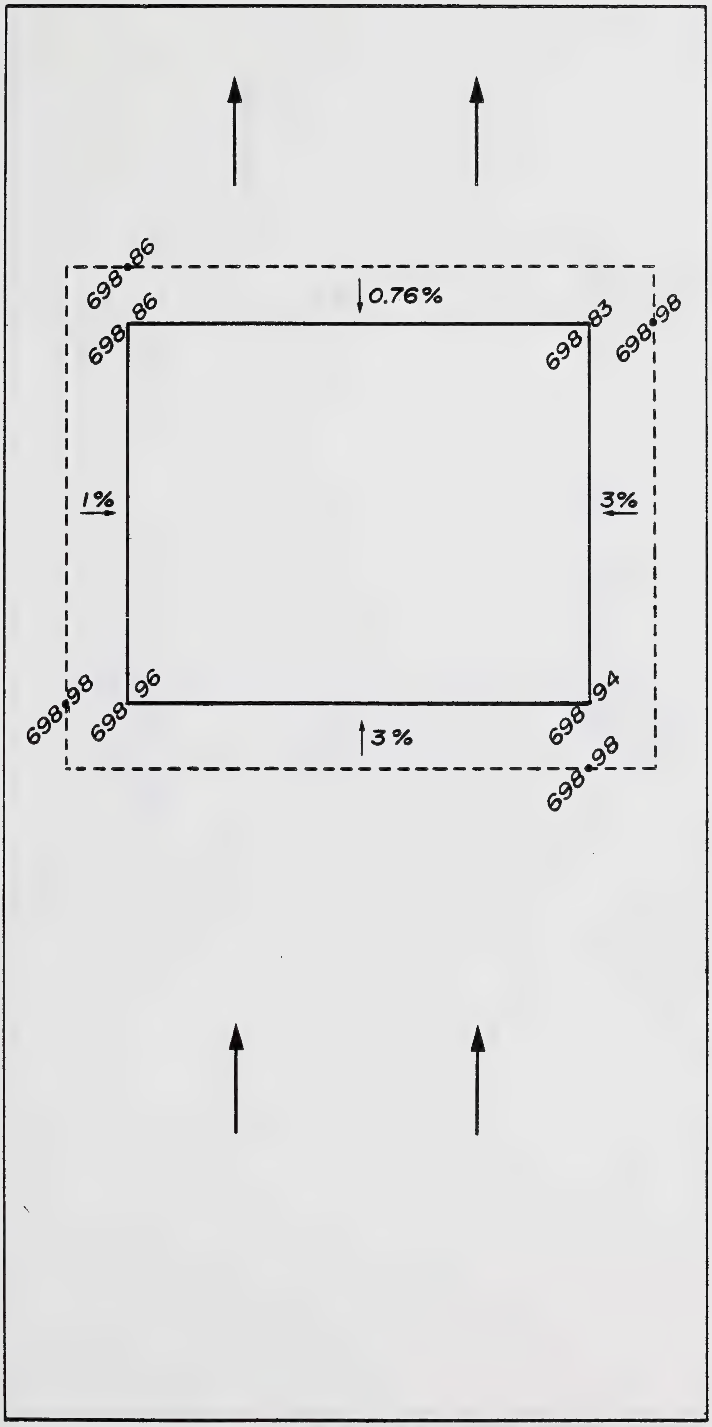


Figure B5 COMPACTED POOR

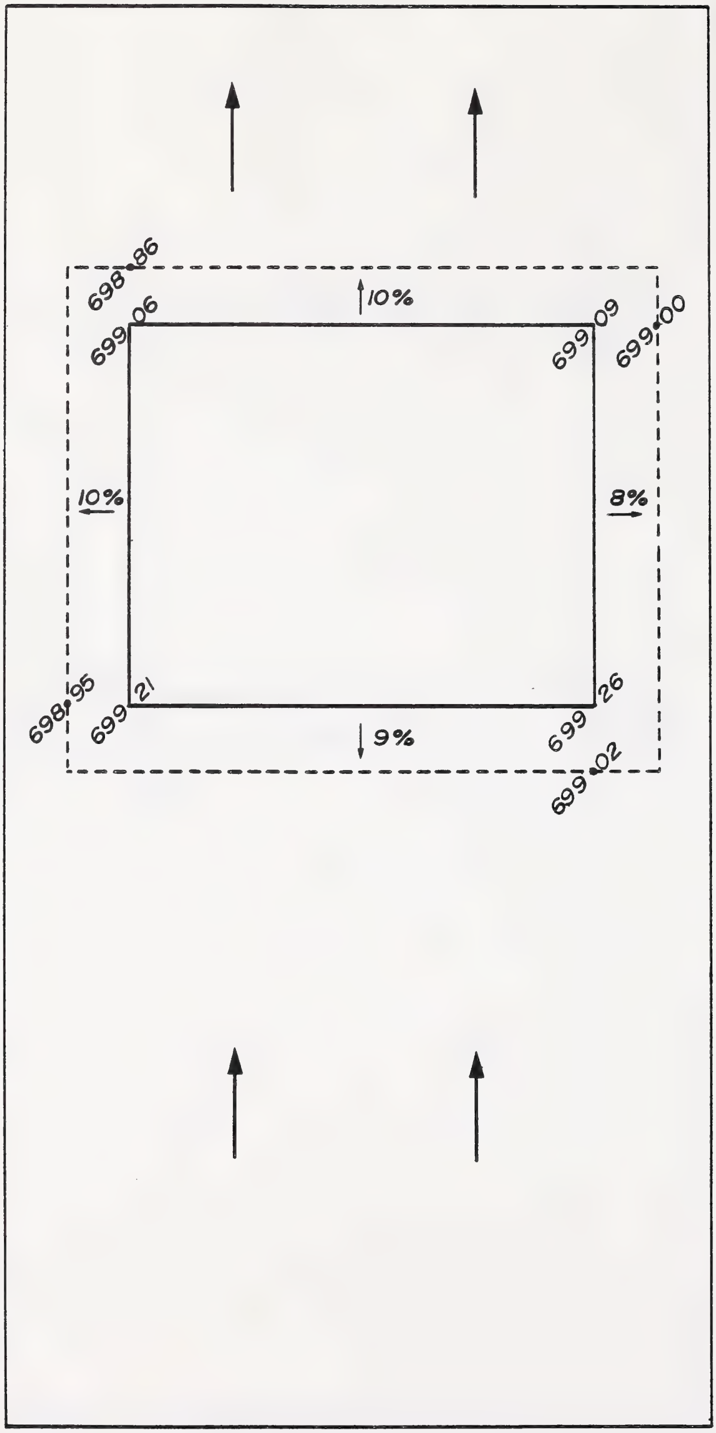


Figure **B6** COMPACTED GOOD

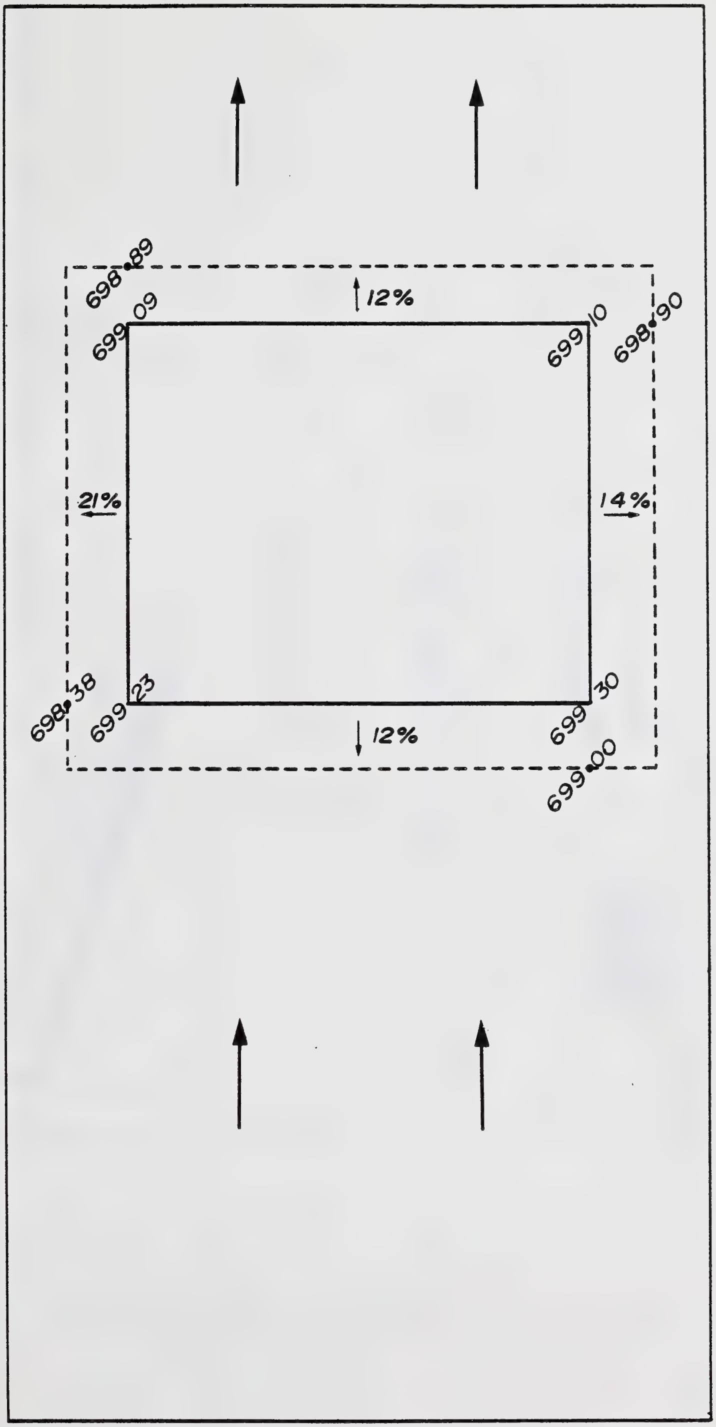
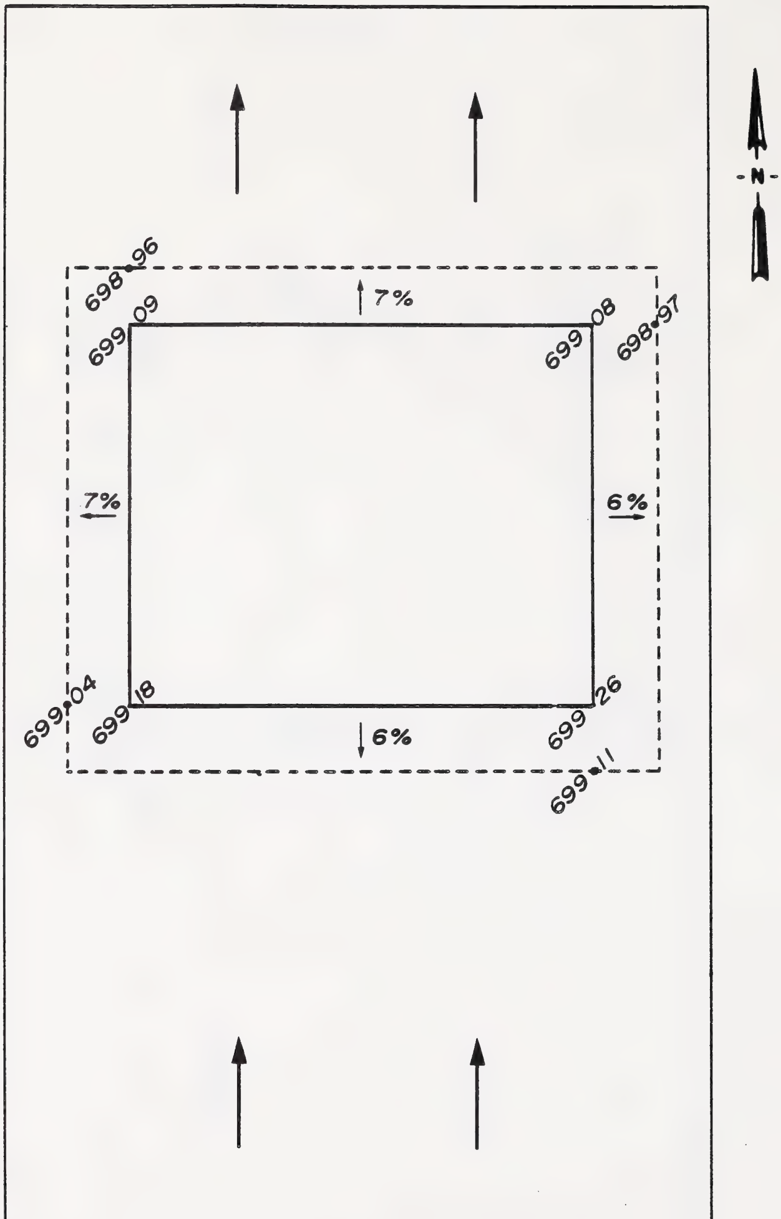


Figure B7 ENGINEERED



Initial site as shown. The backfill settled approximately 250mm during the testing.

Figure B8 UNCOMPACTED BACKFILL

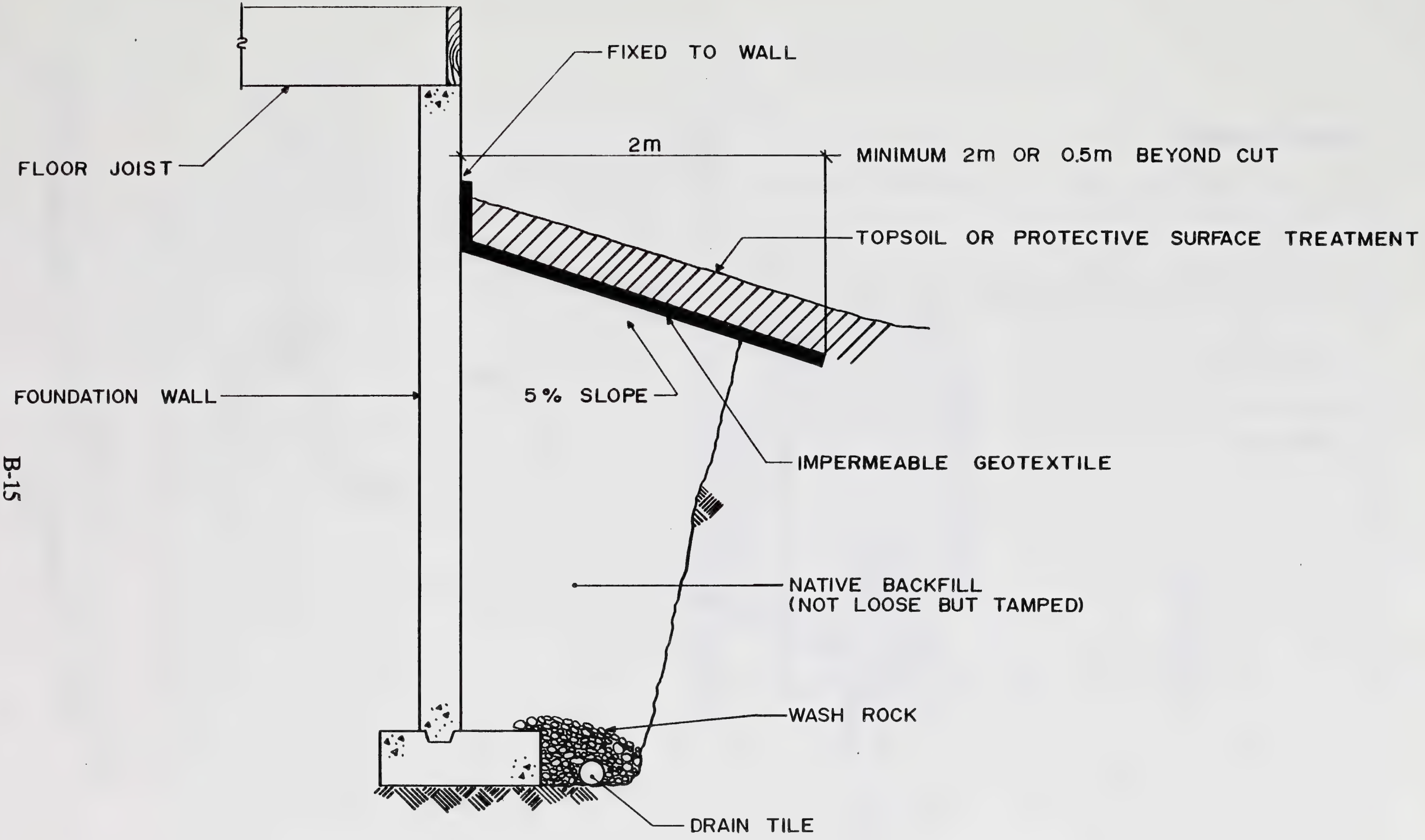


Figure B9 ENGINEERED BACKFILL

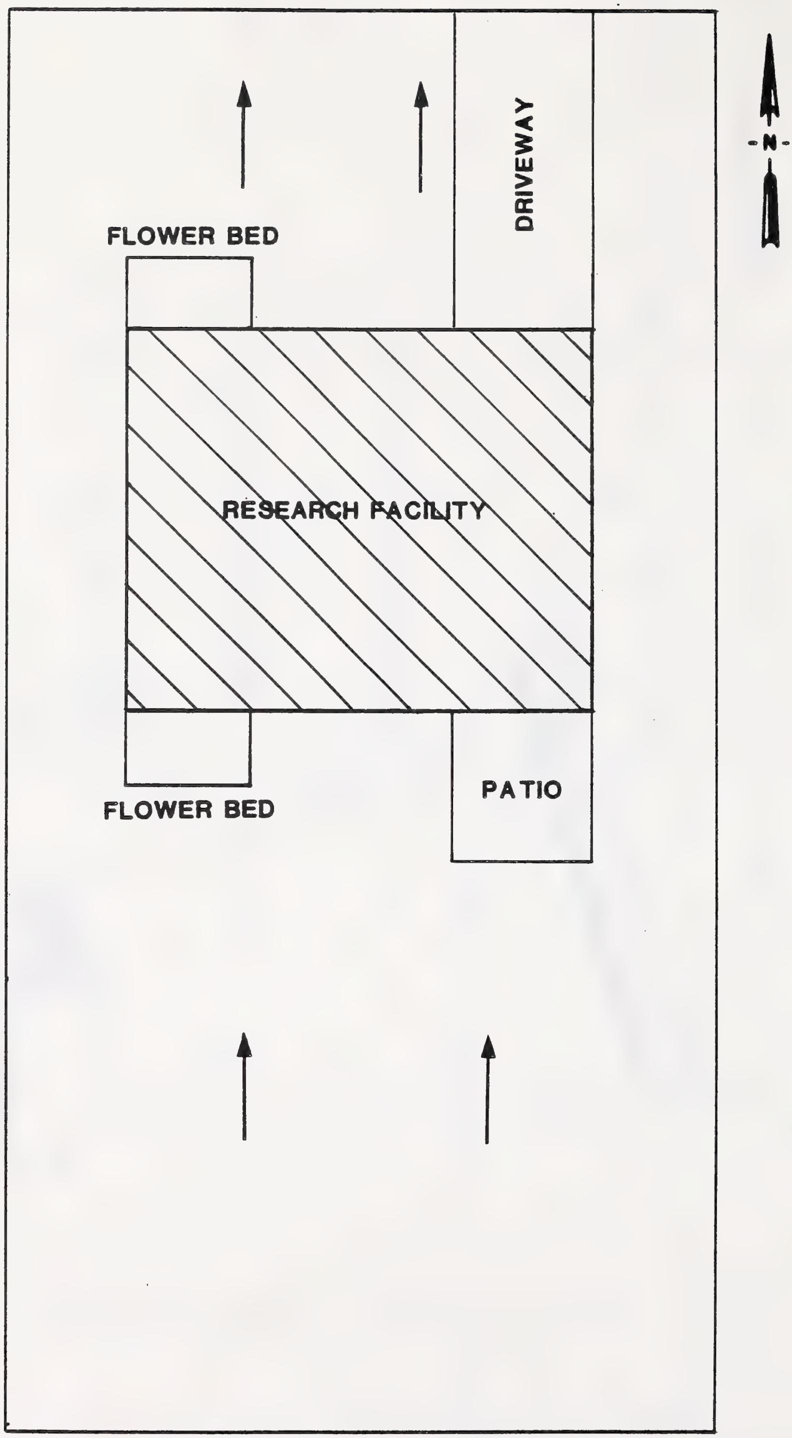


Figure B10 TYPICAL GROUND COVER

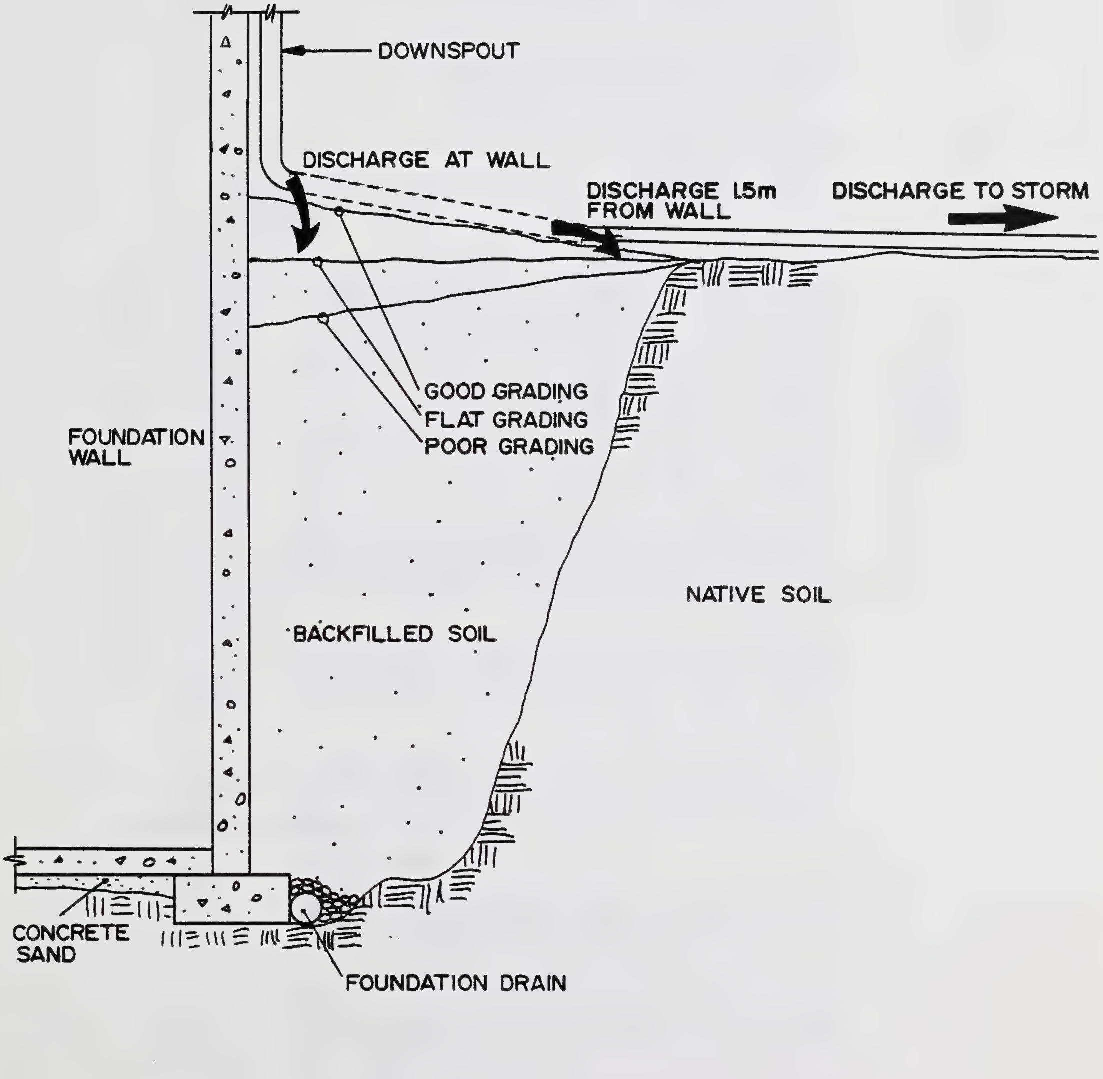
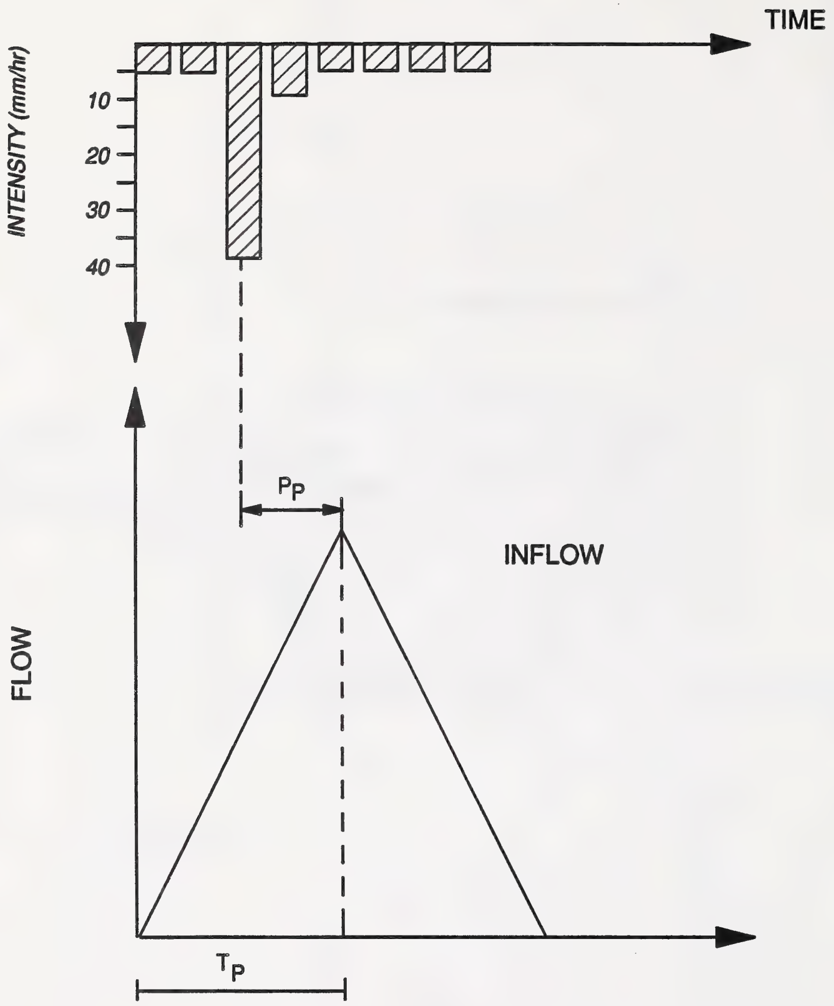


Figure B11 ROOF LEADER LOCATION



T_P - TIME TO PEAK FROM START OF RAINFALL

P_P - TIME TO PEAK FROM PEAK OF HYETOGRAPH

TIME TO PEAK

Figure B12 TIME TO PEAK

SUMMARY OF SIMULATIONS

TEST DATE	STORM	START TIME	VOLUME APPLIED (L)	INTENSITY APPLIED (mm/hr)	PEAK RECORDED INFLOW (L/s)	% ENTERING FOUNDATION DRAIN EXCLUDING NATURAL RAINFALL				TIME TO PEAK (min)		GROUND COVER	ROOF LEADER LOCATION
						FRONT	BACK	TOTAL	BASEFLOW(EXCL.) TOTAL	FROM START	FROM PEAK		
24-May	4-hr/5-yr	10:00	22040	40.38	0.0348			4.20				SOD	1.5m
27-May	4-hr/5-yr	09:30	22040	40.38	0.0366			5.00				SOD	1.5m
29-May	4-hr/5-yr	09:40	22040	40.38	0.0120			2.70				SOD	1.5m
31-May	4-hr/50-yr	12:15	39720	67.31	0.0590			1.70				SOD	1.5m
04-Jun	4-hr/50-yr	09:15	39720	67.31	0.0550			2.10				SOD	1.5m
10-Jun	4-hr/5-yr	10:45	22040	40.38	0.0179			1.70				SOD	WALL
20-Jun	24-hr/5-yr	03:00	35180	12.45	0.0517			6.28		400.46	40.46	SOD	1.5m
25-Jun	24-hr/5-yr	03:00	35180	12.45	0.0444			5.01		411.62	51.62	SOD	1.5m
27-Jun	24-hr/25-yr	03:00	54910	18.54	0.0845			5.21		417.20	57.20	SOD	1.5m
30-Jun	24-hr/25-yr	03:00	52100	18.54	0.0530			2.43		419.50	59.50	SOD	1.5m
02-Jul	4-hr/5-yr	12:30	22040	40.38	0.0739	1.58	2.53	2.18		96.49	21.49	SOD	1.5m
03-Jul	4-hr/5-yr	09:30	22040	40.38	0.0796	1.65	2.45	2.16		85.36	10.36	SOD	1.5m
04-Jul	4-hr/5-yr	10:30	22040	40.38	0.0974			1.90	1.56	81.64	6.64	SOD	STORM
05-Jul	4-hr/5-yr	11:30	22040	40.38	0.0854			2.11	1.77	76.08	1.08	TYPICAL	1.5m
08-Jul	4-hr/5-yr	09:45	22040	40.38	0.0679	1.54	1.97	1.81	1.48	90.92	15.92	TYPICAL	1.5m
10-Jul	24-hr/5-yr	03:00	35180	12.45	0.0274			1.63	1.00	400.46	40.46	TYPICAL	1.5m
14-Jul	4-hr/5-yr	12:00	22040	40.38	0.0384			1.51	1.18	103.91	28.91	BARE	1.5m
15-Jul	4-hr/5-yr	11:00	22040	40.38	0.0562	1.70	1.77	1.74	1.41	92.78	17.78	BARE	1.5m
16-Jul	4-hr/5-yr	08:10	22040	40.38	0.0672	0.83	2.16	1.67	1.34	89.07	14.07	BARE	WALL
18-Jul	4-hr/5-yr	08:00	22040	40.38	0.0305	1.07	1.06	1.07	0.73	111.34	36.34	BARE	STORM

Figure B13 CLAY TILL SOIL
BENCHMARK COMPACTED FLAT

SUMMARY OF SIMULATIONS

TEST DATE	STORM	START TIME	VOLUME APPLIED (L)	INTENSITY APPLIED (mm/hr)	PEAK RECORDED INFLOW (L/s)	% ENTERING FOUNDATION DRAIN EXCLUDING NATURAL RAINFALL				TIME TO PEAK		GROUND COVER	ROOF LEADER LOCATION
						FRONT	BACK	TOTAL	BASEFLOW(EXCL.) TOTAL	FROM START (min)	FROM PEAK (min)		
22-Jul	4-hr/5-yr	15:25	22040	40.38	0.0429	2.43	5.53	4.39	4.05	115.05	40.05	BARE	1.5m
23-Jul	4-hr/5-yr	09:30	22040	40.38	0.0346	2.50	3.94	3.41	3.07	79.79	4.79	BARE	WALL
24-Jul	4-hr/5-yr	10:15	22040	40.38	0.0342	2.56	3.97	3.45	3.12	102.06	27.06	BARE	STORM
25-Jul	4-hr/5-yr	14:30	22040	40.38	0.0415	3.22	3.61	3.47	3.13	92.78	17.78	BARE	1.5m

Figure B14 CLAY TILL SOIL
COMPACTED POOR

SUMMARY OF SIMULATIONS

TEST DATE	STORM	START TIME	VOLUME APPLIED (L)	INTENSITY APPLIED (mm/hr)	PEAK RECORDED INFLOW (L/s)	% ENTERING FOUNDATION DRAIN EXCLUDING NATURAL RAINFALL				TIME TO PEAK		GROUND COVER	ROOF LEADER LOCATION
						FRONT	BACK	TOTAL	BASEFLOW(EXCL.) TOTAL	FROM START	FROM PEAK		
										(min)			
30-Jul	4-hr/5-yr	11:00	22040	40.38	0.0156	0.39	1.63	1.18	0.84	105.77	30.77	BARE	1.5m
31-Jul	4-hr/5-yr	11:30	22040	40.38	0.0206	1.36	1.82	1.65	1.31	98.35	23.35	BARE	STORM
01-Aug	4-hr/5-yr	10:10	22040	40.38	0.1252	1.53	4.56	3.44	3.13	68.65	-6.35	BARE	WALL
02-Aug	4-hr/5-yr	10:00	22040	40.38	0.0233	1.34	1.57	1.49	1.15	89.07	14.07	BARE	1.5m
03-Aug	4-hr/5-yr	10:10	22040	40.38	0.0221	1.83	1.00	1.31	0.97	92.78	17.78	BARE	1.5m
17-Aug	4-hr/5-yr	14:50	22040	40.38	0.0089	0.69	0.54	0.60	0.26			SOD	1.5m
19-Aug	4-hr/5-yr	09:40	22040	40.38	0.0150	0.72	0.85	0.80	0.47	102.60	27.60	SOD	STORM
20-Aug	4-hr/5-yr	11:15	22040	40.38	0.0745	1.23	3.54	2.69	2.36	92.78	17.78	SOD	WALL

Figure B15 CLAY TILL SOIL
COMPACTED GOOD

SUMMARY OF SIMULATIONS

TEST DATE	STORM	START TIME	VOLUME APPLIED (L)	INTENSITY APPLIED (mm/hr)	PEAK RECORDED INFLOW (L/s)	% ENTERING FOUNDATION DRAIN EXCLUDING NATURAL RAINFALL				TIME TO PEAK (min)		GROUND COVER	ROOF LEADER LOCATION
						FRONT	BACK	TOTAL	BASEFLOW(EXCL.) TOTAL	FROM START	FROM PEAK		
10-Aug	4-hr/5-yr	13:05	22040	40.38	0.0209	0.30	2.29	1.56	1.23	100.20	25.20	SOD	1.5m
12-Aug	4-hr/5-yr	09:05	22040	40.38	0.0132	0.41	1.19	0.90	0.57			SOD	1.5m
14-Aug	4-hr/5-yr	10:55	22040	40.38	0.0123	0.50	1.09	0.87	0.54	103.91	28.91	SOD	STORM
15-Aug	4-hr/5-yr	10:35	22040	40.38	0.0275	0.41	1.31	0.98	0.64	87.21	12.21	SOD	WALL

Figure B16 CLAY TILL SOIL
ENGINEERED BACKFILL

SUMMARY OF SIMULATIONS

TEST DATE	STORM	START TIME	VOLUME APPLIED (L)	INTENSITY APPLIED (mm/hr)	PEAK RECORDED INFLOW (L/s)	% ENTERING FOUNDATION DRAIN EXCLUDING NATURAL RAINFALL				TIME TO PEAK		GROUND COVER	ROOF LEADER LOCATION
						FRONT	BACK	TOTAL	BASEFLOW(EXCL.) TOTAL	FROM START (min)	FROM PEAK (min)		
26-Aug	4-hr/5-yr	13:20	22040	40.38	0.7005	16.87	17.64	17.36	17.02	94.63	19.63	BARE	1.5m
27-Aug	4-hr/5-yr	10:45	22040	40.38	0.4457	10.50	13.59	12.46	12.12	111.34	36.34	BARE	STORM
28-Aug	4-hr/5-yr	09:45	22040	40.38	1.1219	46.02	22.06	30.87	30.56	81.64	6.64	BARE	WALL
30-Aug	4-hr/5-yr	09:50	22040	40.38	1.0315	26.92	27.81	27.48	27.14	81.86	6.86	BARE	1.5m
SUMP PUMP LOCATION VARIED													
03-Sep	4-hr/5-yr	09:40	22040	40.38	0.8777			28.43	28.10	90.92	15.92	BARE	1.5m
05-Sep	4-hr/5-yr	09:40	22040	40.38	2.7299			156.16	155.83	83.50	8.50	BARE	1.5m
06-Sep	4-hr/5-yr	12:30	22040	40.38	2.3902			131.16	130.82	76.08	1.08	BARE	1.5m
07-Sep	4-hr/5-yr	11:15	22040	40.38	2.7484			73.55	73.22	96.49	21.49	BARE	1.5m

Figure B17 CLAY TILL SOIL
UNCOMPACTED BACKFILL

APPENDIX C

GEOTECHNICAL INFORMATION

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SOILS REPORT

EBA CONSULTANTS ENGINEERING LTD.

INSTRUMENTATION INSTALLATION AND LABORATORY TESTING COUNTY OF STRATHCONA FOUNDATION DRAIN TEST SITE

Submitted to:

CH2M HILL ENGINEERING LTD.

0106-10455

OCTOBER, 1990

EBA Engineering Consultants Ltd.

Civil, Geotechnical and Materials Engineers

1990 10 11

CH2M Hill Engineering Ltd.
#203, 10240 - 124 Street
Edmonton, Alberta
T5N 3W6

EBA File: 0106-10455

Attention: Mr. Jerry Johnson, P.Eng.

Subject: Instrumentation Installation and Laboratory Testing
County of Strathcona
Foundation Drain Test Site

1.0 INTRODUCTION

EBA Engineering Consultants Ltd. (EBA) has been retained to install standpipe piezometers for a foundation drain test site. In conjunction with this phase of the project, laboratory testing of soil samples obtained in the field was also conducted.

The project site is situated at an existing County of Strathcona water reservoir storage site, which is located at 17 Street and 92 Avenue, east of the Edmonton city limits. The area designated as the test site occupies the northeast corner of the property. At the time of the field work, the site was relatively level with a gentle slope to the north. The surface of the site was grassed and access for the drill rig was good.

2.0 FIELD WORK

Field work was carried out on September 20, 1990 utilizing a truck-mounted drill rig equipped with 150 mm diameter solid flight augers. A total of 10 boreholes were drilled to depths ranging from 1.2 to 3.0 m. There were 4 primary borehole locations as shown on the attached Figure 1. At each location, a 3.0 m deep borehole was drilled with relatively undisturbed Shelby tube soil samples taken at 500 mm intervals. On completion, a 25 mm diameter standpipe piezometer was installed using clean sand around the lower slotted portion of the standpipe (bottom 400 to 500 mm) and sealed with bentonite. Cuttings were used to backfill the balance of the borehole and a bentonite seal was placed at the surface. A 150 mm diameter steel culvert was installed at the surface to provide protection for these standpipes.

A second borehole 1.2 m deep was drilled approximately 3.0 m from the initial borehole at each location and a standpipe installed. No soil sampling was performed for these shallow boreholes. Similar to the initial installation, clean sand was used to backfill the lower slotted portion of the standpipe and bentonite was used to seal off the sand. No steel casing was used to protect the second standpipe installation. Details of each standpipe installation is presented in Appendix C.

Two additional boreholes were drilled to a depth of 1.5 m at the locations shown on Figure 1, denoted as 'HC'. One Shelby tube soil sample was taken in each borehole at this depth. No standpipes were installed in either borehole.

3.0 LABORATORY TESTING

All the Shelby tube soil samples were returned to the laboratory to determine a unit weight density and moisture content of the soil. A summary of the moisture contents, wet density and dry density of the soil samples is presented on the attached table.

The 2 samples obtained from the 'HC' boreholes were tested to determine the permeability of the soil based on a constant head laboratory permeability test. Samples were trimmed to a diameter of approximately 70 mm and height of 25 mm. The samples were protected with a double latex membrane, installed in a triaxial cell and back-pressure saturated. A differential pressure of 34.5 kPa (5 psi) was applied across the sample and the test run until a uniform flow was achieved through the sample. Results of constant head laboratory permeability test are as follows:

Borehole	Initial Moisture Content (%)	Initial Wet Density (kg/m³)	Final Moisture Content (%)	Final Wet Density (kg/m³)	Permeability (m/sec)
HC2	10.9	1964	18.2	2083	1.1×10^{-9}
HC4	29.5	1844	28.6	1862	6.4×10^{-11}

4.0 SOIL STRATIGRAPHY

The soil stratigraphy is extremely variable across the site. The majority of the area appears to be fill to a depth of at least 3.0 m. The fill is highly variable ranging from topsoil to clay to clay till to clay shale. Detailed logs of the boreholes are presented in Appendix B.

This stratigraphy appears unusual, as the existing surface topography does not visually appear to be a fill area. It is understood that the present site facilities which consists of several concrete and cinder block structures was constructed in 1972.

A set of 1967 aerial photographs of the site were obtained to view the original site conditions prior to the present development. The aerial photographs indicate that in 1967, the southwest corner of the site was occupied by an above grade water reservoir retained with soil berms. An L-shaped excavation is visible along the north and east edge of the property. It appears that borrow was used from this excavation to construct the soil berms.

At present, the earth berm water reservoir does not exist. It is believed that when the former reservoir was abandoned, the borrow area was infilled with the soil from the berms. This explains why such a depth of fill was encountered during the drilling program.

5.0 CLOSURE

We trust the attached information satisfies your present requirements. Should you have any questions or concerns, please contact our office at your convenience.

EBA Engineering Consultants Ltd.

A. F. RUBAN
A. Ruban
91-01-07

A.F. Ruban, P. Eng.
Senior Project Engineer

R. DUBAS

R. Dubas, P. Eng.
Senior Project Director

AFR/RD/vm

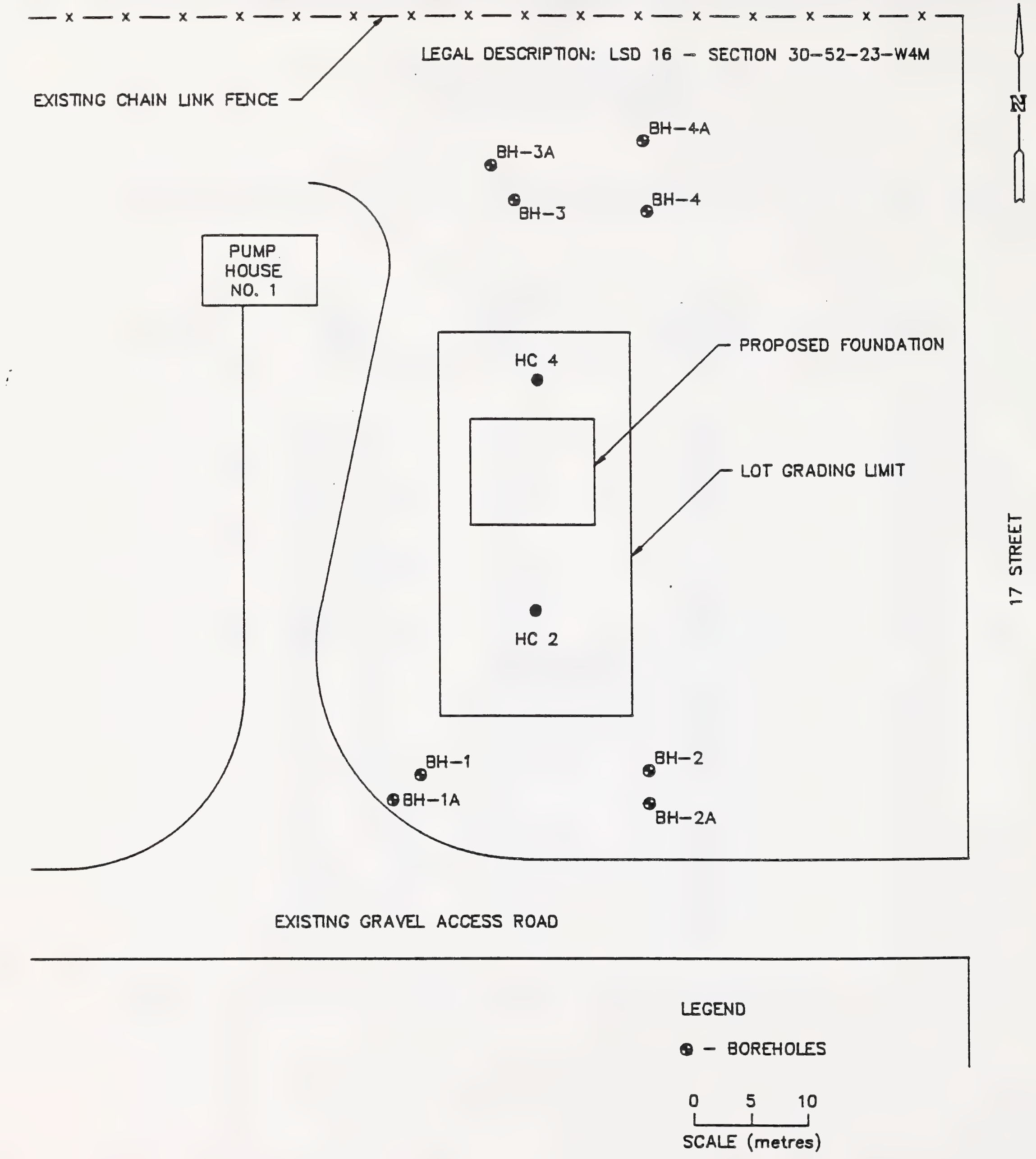
PERMIT TO PRACTICE
EBA ENGINEERING CONSULTANTS LTD.
Signature A. Ruban
Date 91-01-07
PERMIT NUMBER: P 245
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

SUMMARY OF UNIT WEIGHT DENSITIES
COUNTY OF STRATHCONA
FOUNDATION DRAIN TEST SITE

Borehole	Depth (m)	Moisture Content (%)	Wet Density (kg/m^3)	Dry Density (kg/m)
1	0.5 - 0.85	15.4	2075	1798
	1.2 - 1.7	15.7	2154	1861
	1.7 - 2.0	19.1	2004	1682
	2.0 - 2.35	18.6	2022	1705
	2.5 - 2.9	18.1	2122	1798
2	0.5 - 0.85	11.1	1870	1684
	1.0 - 1.35	8.0	*	*
	1.5 - 1.8	10.0	2126	1933
	2.0 - 2.2	15.9	1955	1686
	2.5 - 2.75	18.1	2018	1709
3	0.5 - 0.7	13.0	2083	1780
	1.0 - 1.3	17.6	1888	1671
	1.5 - 1.8	17.0	2080	1768
	2.0 - 2.25	18.1	2079	1761
	2.5 - 3.0	27.1	1929	1518
4	0.5 - 1.0	14.8	1635	1424
	1.0 - 1.25	14.8	2053	1787
	1.5 - 1.75	14.8	2155	1877
	2.0 - 2.4	20.2	2030	1689
	2.5 - 2.9	16.6	2085	1788

NOTE: * Sample too dry and crumbly, no density possible

FIGURES



Note: Based on lot grading plan prepared by CH2M Hill Engineering Ltd.

EBA Engineering Consultants Ltd.			PROJECT	COUNTY OF STRATHCONA FOUNDATION DRAIN TEST SITE	
CLIENT **CH2M HILL ENGINEERING LTD.**			TITLE	**SITE PLAN AND BOREHOLE LOCATIONS**	
DATE 90–10–17	DWN. DM	CHKD. AFR	FILE NO.	10455001	FIGURE 1

APPENDIX B

BOREHOLE LOGS

TERMS USED ON BOREHOLE LOGS

TERMS DESCRIBING CONSISTENCY OR CONDITION

COARSE GRAINED SOILS (major portion retained on 0.075mm sieve): includes (1) clean gravels and sands, and (2) silty or clayey gravels and sands. Condition is rated according to relative density, as inferred from laboratory or in situ tests.

DESCRIPTIVE TERM	RELATIVE DENSITY	N (blows per 0.3m)
Very Loose	0 to 20%	0 to 4
Loose	20 to 40%	4 to 10
Compact	40 to 75%	10 to 30
Dense	75 to 90%	30 to 50
Very Dense	90 to 100%	greater than 50

The number of blows, N, on a 51mm O.D. split spoon sampler of a 63.5kg weight falling 0.76m, required to drive the sampler a distance of 0.3m from 0.15m to 0.45m.

FINE GRAINED SOILS (major portion passing 0.075mm sieve): includes (1) inorganic and organic silts and clays, (2) gravelly, sandy, or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength, as estimated from laboratory or in situ tests.

DESCRIPTIVE TERM	UNCONFINED COMPRESSIVE STRENGTH (kPa)
Very Soft	Less Than 25
Soft	25 to 50
Firm	50 to 100
Stiff	100 to 200
Very Stiff	200 to 400
Hard	Greater Than 400

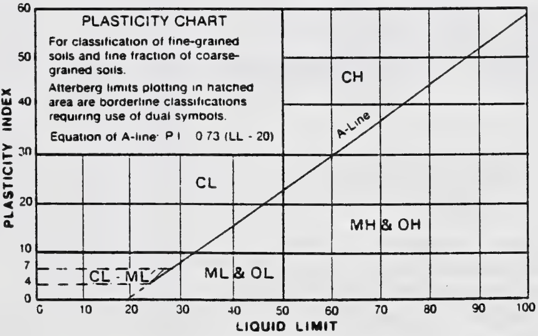
NOTE: Slickensided and fissured clays may have lower unconfined compressive strengths than shown above, because of planes of weakness or cracks in the soil.

GENERAL DESCRIPTIVE TERMS

Slickensided	- having inclined planes of weakness that are slick and glossy in appearance.
Fissured	- containing shrinkage cracks, frequently filled with fine sand or silt; usually more or less vertical.
Laminated	- composed of thin layers of varying colour and texture.
Interbedded	- composed of alternate layers of different soil types.
Calcareous	- containing appreciable quantities of calcium carbonate.
Well Graded	- having wide range in grain sizes and substantial amounts of intermediate particle sizes.
Poorly graded	- predominantly of one grain size, or having a range of sizes with some intermediate size missing.

eba

UNIFIED SOIL CLASSIFICATION †

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES	CLASSIFICATION CRITERIA		
COARSE-GRAINED SOILS More than 50% retained on No 200 sieve *	GRAVELS 50% or more of coarse fraction retained on No 4 sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines	Classification on basis of percentage of fines Less than 5% Pass No. 200 sieve GW, GP, SW, SP More than 12% Pass No 200 sieve GM, GC, SM, SC 5% to 12% Pass No 200 sieve Borderline Classification requiring use of dual symbols	$C_u = D_{60}/D_{10}$ Greater than 4 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines		Not meeting both criteria for GW	
		GRAVELS WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures		Atterberg limits plot below "A" line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures		Atterberg limits plot above "A" line and plasticity index greater than 7	
	SANDS More than 50% of coarse fraction passes No. 4 sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines.		$C_u = D_{60}/D_{10}$ Greater than 6 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			SP	Poorly graded sands and gravelly sands, little or no fines		Not meeting both criteria for SW	
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures		Atterberg limits plot below "A" line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures		Atterberg limits plot above "A" line and plasticity index greater than 7	
FINE-GRAINED SOILS 50% or more passes No 200 sieve *	SILTS AND CLAYS Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands			
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL	Organic silts and organic silty clays of low plasticity			
	SILTS AND CLAYS Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts			
			CH	Inorganic clays of high plasticity, fat clays			
			OH	Organic clays of medium to high plasticity			
HIGHLY ORGANIC SOILS			Pt	Peat, muck and other highly organic soils			

PLASTICITY CHART

For classification of fine-grained soils and fine fraction of coarse-grained soils.

Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols.

Equation of A-line: P I 0 73 (LL - 20)

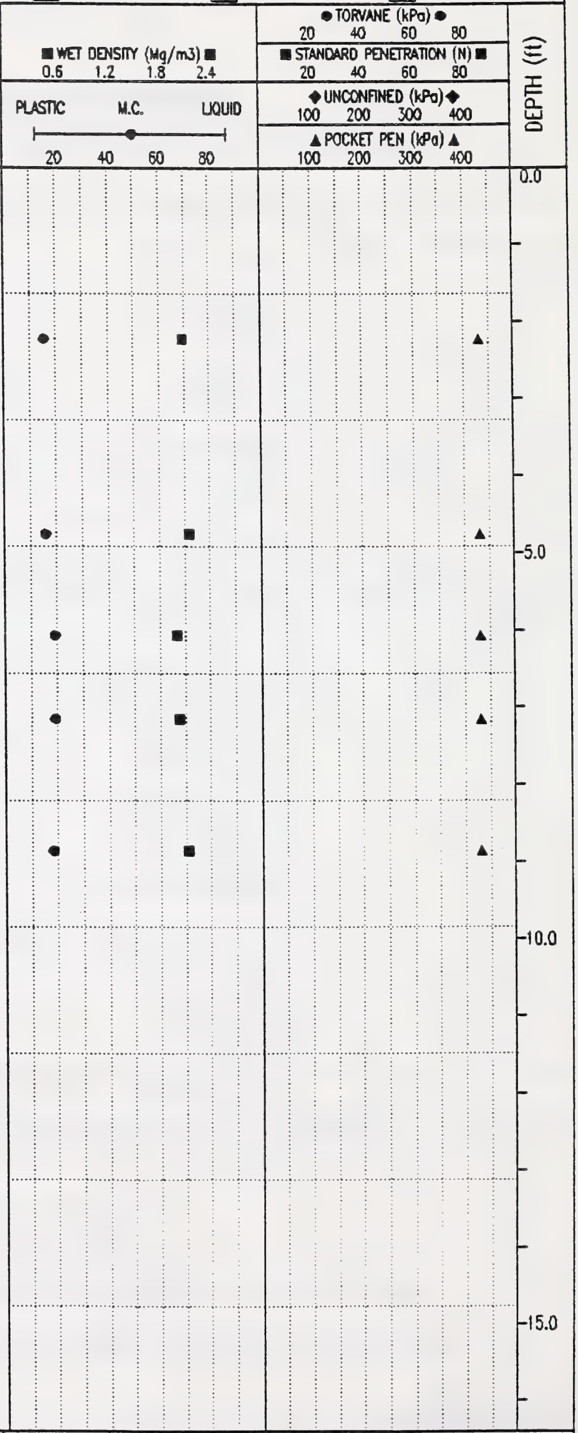
* Based on the material passing the 3-in. (75-mm) sieve

† ASTM Designation D 2487

COUNTY OF STRATHCONA	CH2M HILL	BOREHOLE No. 10455-01
FOUNDATION DRAIN TEST SITE	DRILL: B-61, SOLID FLIGHT AUGER	Project No: 0106-10455
SHERWOOD PARK, ALBERTA		ELEVATION 0.00 (m)

SAMPLE TYPE ■ DISTURBED ◪ NO RECOVERY ☒ SPT ▤ A-CASING ◫ SHELBY TUBE ◫ CORE

DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	USC
0.0	TOPSOIL – (150mm thick)			
	CLAY (FILL) – silty, trace of pebbles and oxides, damp, hard, olive brown			
-1.0				
	– trace of organics, rootlets, organic odour			
-2.0				
	– 300mm layer – reddish brown iron oxides, crumbly, damp			
	CLAY SHALE (FILL) – weathered, reworked			
-3.0	END OF BOREHOLE (2.9 metres) slough – none at 0 hrs. water – dry at 0 hrs. Standpipe installed to 2.9 metres. Second standpipe installed in separate hole approximately 2.5 metres away at depth of 1.2 metres. (Standpipes installed with bentonite seals)			
-4.0				
5.0				

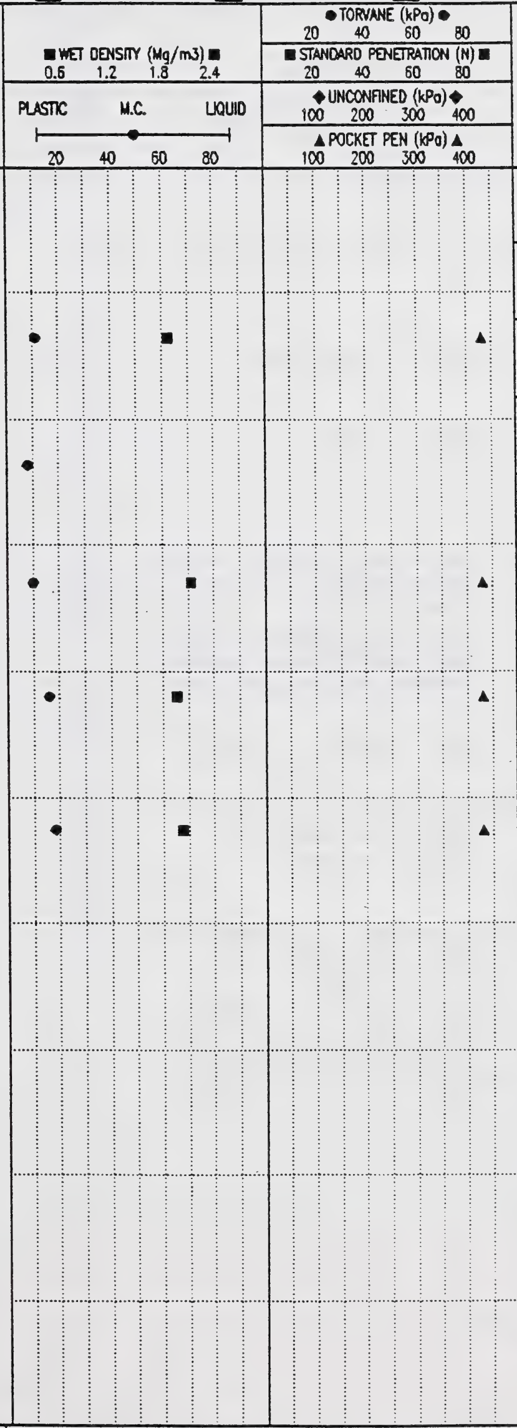


EBA Engineering Consultants Ltd. Edmonton, Alberta	COMPLETION DEPTH 2.9 m	COMPLETE 90/09/20	
	LOGGED BY AOC	DWG NO.10455-01	Page 1 of 1

COUNTY OF STRATHCONA	CH2M HILL	BOREHOLE No. 10455-02
FOUNDATION DRAIN TEST SITE	DRILL: B-61, SOLID FLIGHT AUGER	Project No: 0106-10455
SHERWOOD PARK, ALBERTA		ELEVATION 0.00 (m)

SAMPLE TYPE ■ DISTURBED ▨ NO RECOVERY ☒ SPT ▤ A-CASING ▯ SHELBY TUBE ▯ CORE

DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	USC	DEPTH (ft)
0.0	TOPSOIL – (130mm thick)				0.0
	CLAY (FILL) – silty, trace of organics and pebbles, rootlets, damp, hard, brown				
	– trace of coal and gravel to 25mm maximum diameter, light olive brown				
1.0					
	– trace of gravel to 30mm maximum diameter, fragments, possible trace of sulphates				5.0
2.0	– laminated, moist				
	– trace of iron oxides, becoming weathered shale, 150mm sand layer – silty, damp, light olive				
	– laminated, weathered shale				
3.0	END OF BOREHOLE (3.0 metres) slough – none at 0 hrs. water – dry at 0 hrs. Standpipe installed to 3.0 metres. Second standpipe installed 2.5 metres away at a depth of 1.05 metres. (Standpipes installed with bentonite seals)				10.0
4.0					
					15.0
5.0					

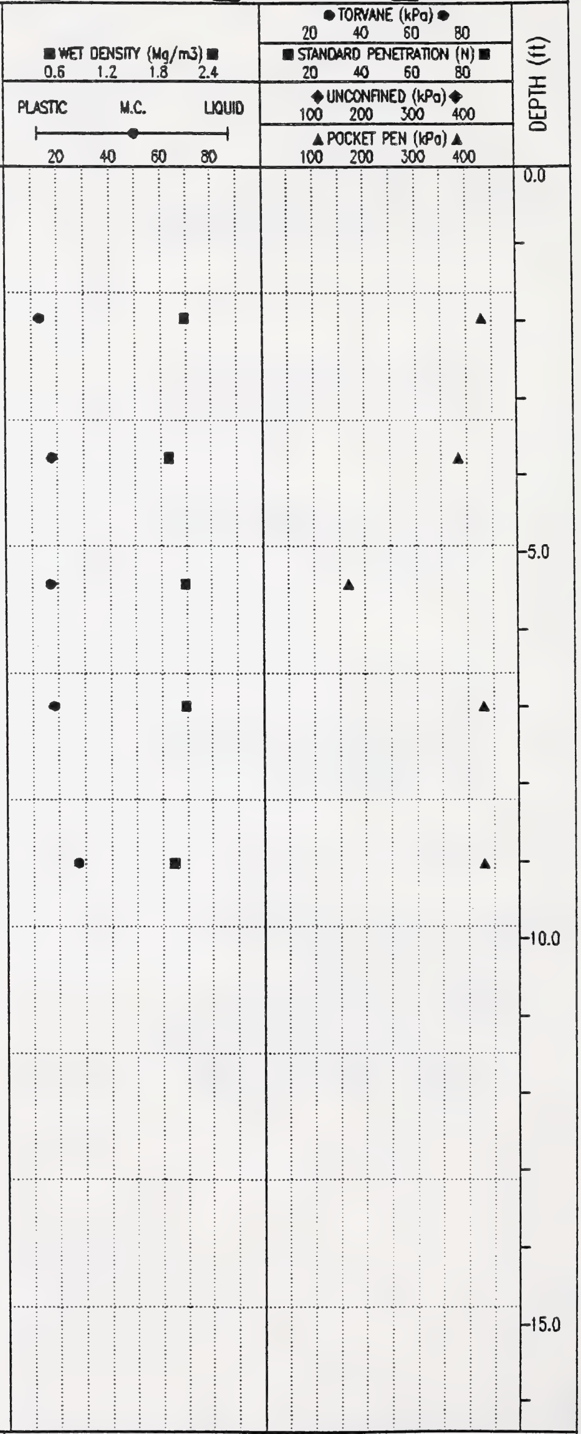


EBA Engineering Consultants Ltd. Edmonton, Alberta	COMPLETION DEPTH 3.0 m	COMPLETE 90/09/20
	LOGGED BY AOC	DWG NO.10455-02 Page 1 of 1

COUNTY OF STRATHCONA	CH2M HILL	BOREHOLE No. 10455-03
FOUNDATION DRAIN TEST SITE	DRILL: B-61, SOLID FLIGHT AUGER	Project No: 0106-10455
SHERWOOD PARK, ALBERTA		ELEVATION 0.00 (m)

SAMPLE TYPE ■ DISTURBED ◪ NO RECOVERY ☒ SPT ▤ A-CASING ▯ SHELBY TUBE ▮ CORE

DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	USC
0.0	TOPSOIL – (300mm thick)			
	CLAY (FILL) – silty, damp, hard, olive brown – moist, dark greyish brown	▯		
1.0	– organics and roots	▯		
	– trace of gravel to 30mm maximum diameter, fragments, firm, light brown – trace of coal inclusions and iron oxides, possible trace of sulphates, laminated, moist, medium plastic	▯		
2.0	– trace of sulphates, iron staining	▯		
	CLAY SHALE (FILL) – trace of coal, coal inclusions, iron staining, disturbed, reworked	▯		
3.0	END OF BOREHOLE (3.0 metres) slough – none at 0 hrs. water – dry at 0 hrs. Standpipe installed to 3.0 metres. Second standpipe installed 3.0 metres away at a depth of 1.2 metres. (Standpipes installed with bentonite seals)			
4.0				
5.0				

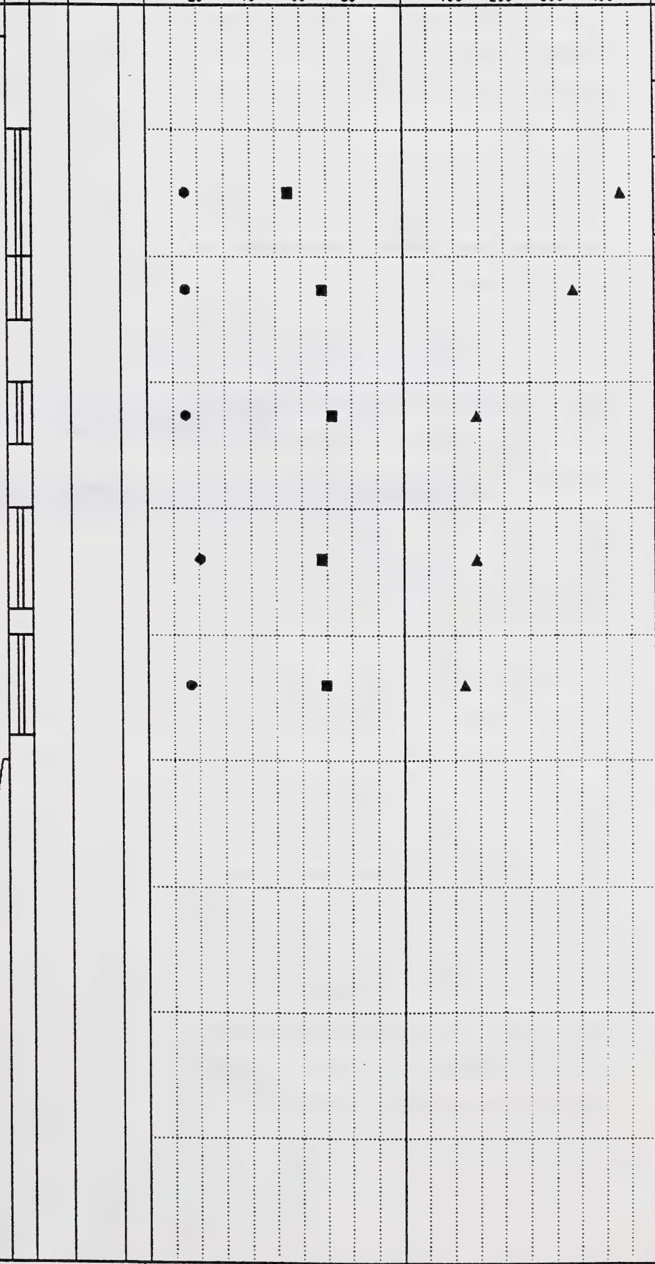


EBA Engineering Consultants Ltd. Edmonton, Alberta	COMPLETION DEPTH 3.0 m	COMPLETE 90/09/20
	LOGGED BY AOC	DWG NO.10455-03 · Page 1 of 1

COUNTY OF STRATHCONA	CH2M HILL	BOREHOLE No. 10455-04
FOUNDATION DRAIN TEST SITE	DRILL: B-61, SOLID FLIGHT AUGER	Project No: 0106-10455
SHERWOOD PARK, ALBERTA		ELEVATION 0.00 (m)

SAMPLE TYPE ■ DISTURBED ▨ NO RECOVERY ☒ SPT ▤ A-CASING ◫ SHELBY TUBE ◫ CORE

DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	USC	■ WET DENSITY (Mg/m3) ■ 0.6 1.2 1.8 2.4 / PLASTIC M.C. LIQUID 20 40 60 80	● TORVANE (kPa) ● 20 40 60 80 / ■ STANDARD PENETRATION (N) ■ 20 40 60 80 / ◆ UNCONFINED (kPa) ◆ 100 200 300 400 / ▲ POCKET PEN (kPa) ▲ 100 200 300 400	DEPTH (ft)
0.0	TOPSOIL – (130mm thick)						0.0
	CLAY (FILL) – silty, trace of organics, rootlets, damp, hard, dark brown						
1.0	– trace of gravel to 20mm maximum diameter, some laminae containing sand, moist, very stiff						5.0
	– trace of pebbles and sand, firm, olive brown						
2.0	– small sand lense – 80mm thick topsoil layer, organic odour						
	– trace of coal inclusions, possible trace of sulphates, dark greyish brown – trace of iron oxides, mottled brown/ grey						
3.0	– coal seam – trace of wood and roots, pockets of black clay with an organic odour, (200mm thick)						10.0
	END OF BOREHOLE (3.0 metres) slough – none at 0 hrs. water – dry at 0 hrs. Standpipe installed to 3.0 metres. Second standpipe installed 3.0 metres away at a depth of 1.2 metres. (Standpipes installed with bentonite seals)						
4.0							15.0
5.0							



EBA Engineering Consultants Ltd. Edmonton, Alberta	COMPLETION DEPTH 3.0 m	COMPLETE 90/09/20
	LOGGED BY AOC	DWG NO.10455-04 Page 1 of 1

APPENDIX C

STANDPIPE INSTALLATION DETAILS

STANDPIPE/PIEZOMETER INSTALLATION REPORT

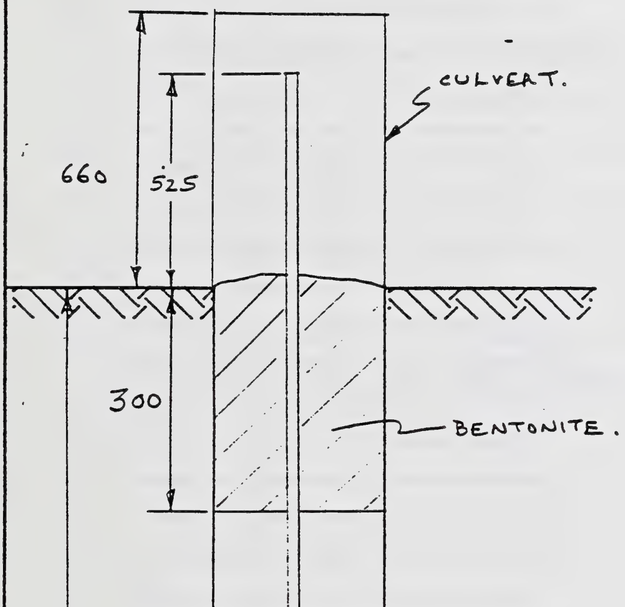
PROJECT COUNTY OF STRATHCONA TEST SITE.

PROJECT No. 0106-10455

DATE INSTALLED 20 SEP. '90.

BOREHOLE No. B. H. ①.

NOTE:



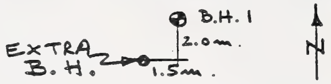
STANDPIPE/PIEZOMETER INSTALLATION REPORT

PROJECT COUNTY OF STRATHCONA. TEST SITE.

PROJECT No. 0106-10455

DATE INSTALLED 20 SEP. '90.

BOREHOLE No. EXTRA B.H. BY BH.①.



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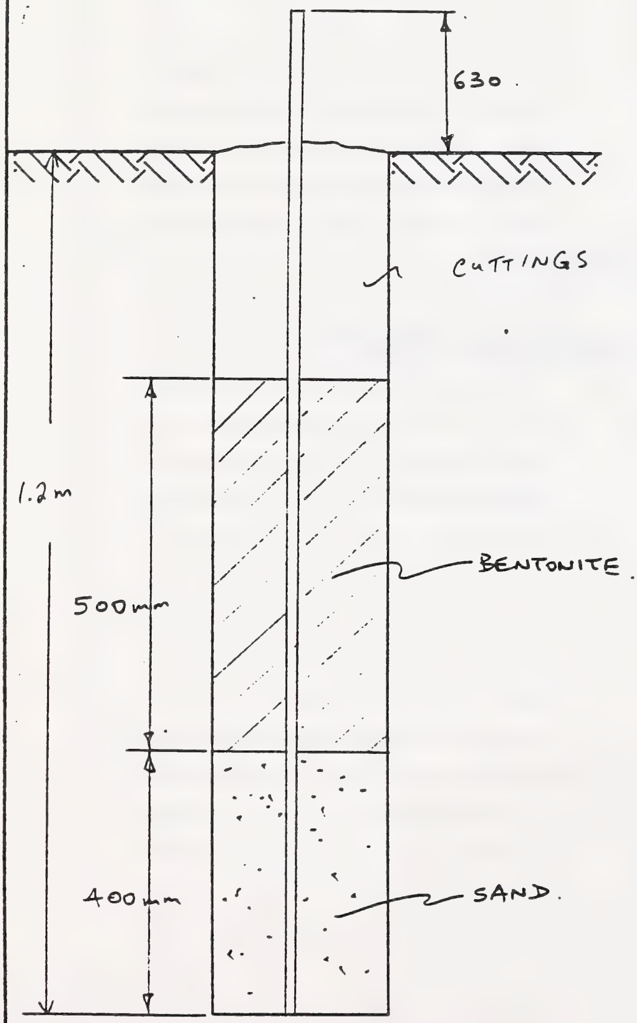

2.0 PIEZOMETER DETAILS

On May 1, 1991 16 piezometers were installed around the perimeter of the foundation. These piezometers were installed after the site was graded and backfilled, while the EBA piezometers were installed before construction.

The piezometers were located systematically around the foundation as illustrated on Figure C1. The piezometers were placed within the backfill zone to provide groundwater information above the foundation drain, in the native soil, and at the boundary between native soil and the backfill. The typical orientation of the piezometers in the backfill zone is shown on Figure C2.

Piezometers 1, 2, 3, 4, 5, and 6 were equipped with water level recorders. The water level recorders are a float and weight assembly connected to a data logger.

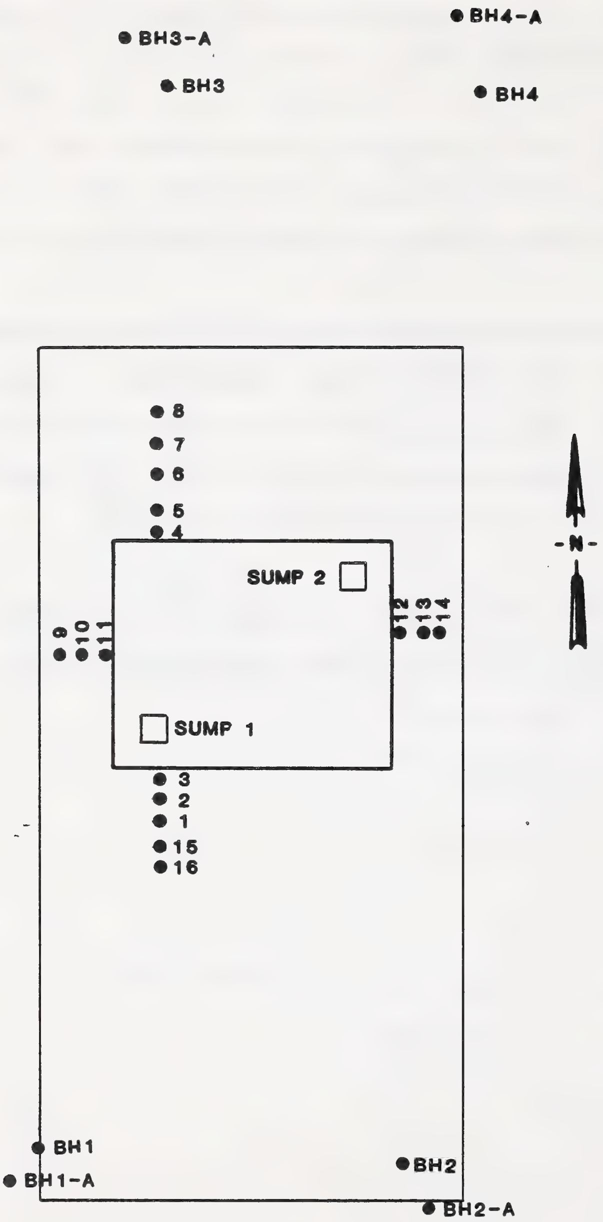

Figure C1 PIEZOMETER LOCATIONS

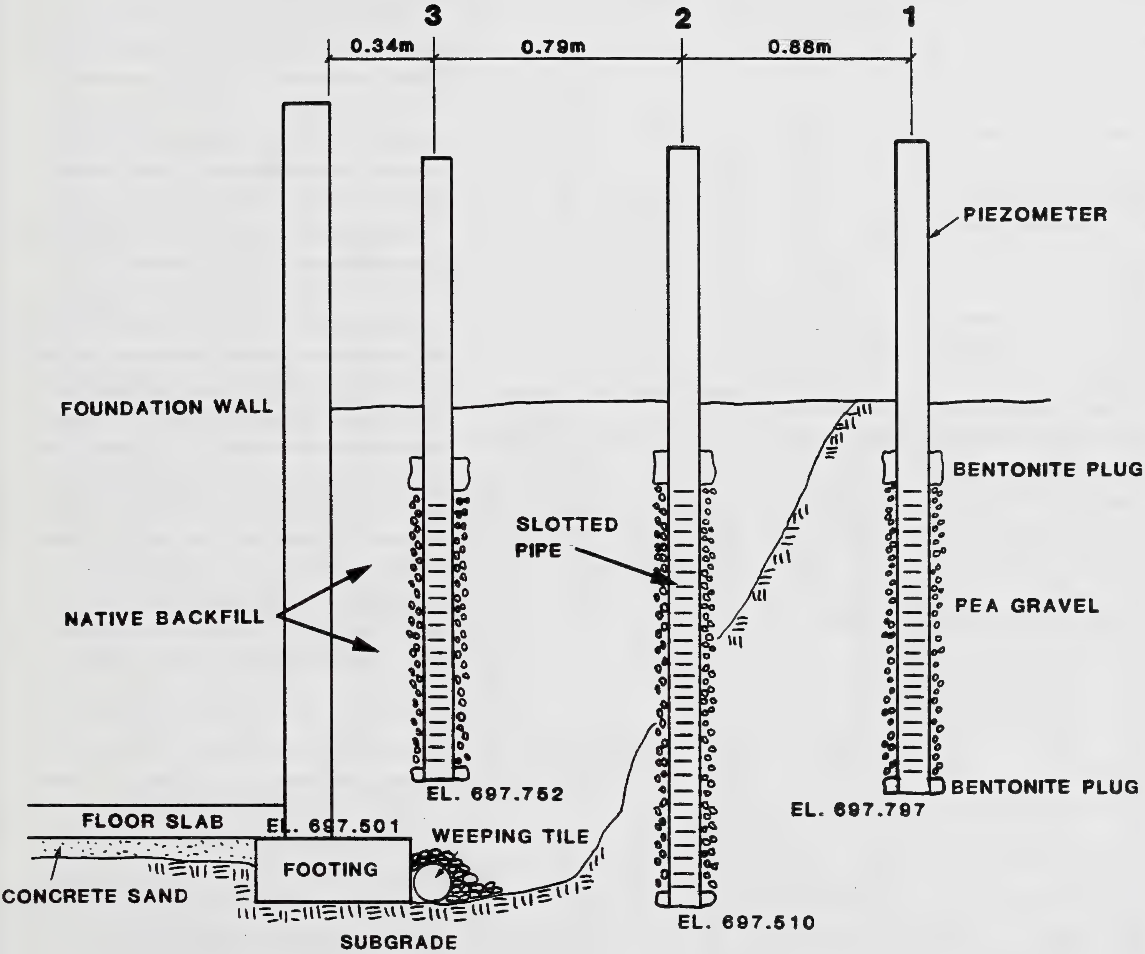

Figure C2 TYPICAL PIEZOMETER ORIENTATION TO FOUNDATION WALL AND BACKFILL ZONE

STRATHCONA COUNTY RESEARCH FACILITY
PIEZOMETER INSTALLATION REPORT

DATE INSTALLED 1991 MAY 1

PROJECT NO. EDM23269.A0

BOREHOLE NO. 1

NOTE: PROFILE OF PIEZOMETER LOOKING NORTH

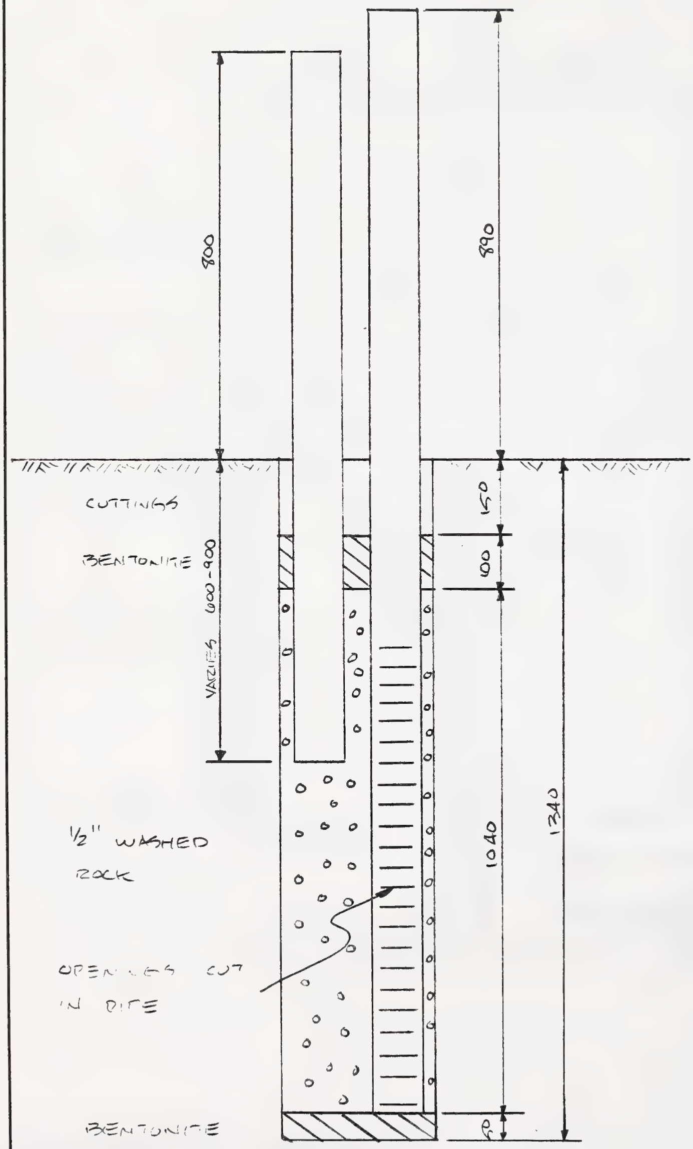

Figure C3

CH2M HILL

STRATHCONA COUNTY RESEARCH FACILITY
PIEZOMETER INSTALLATION REPORT

DATE INSTALLED 1991 MAY 1

PROJECT NO. EDM23269.A0

BOREHOLE NO. 2

NOTE:

PROFILE OF PIEZOMETER

LOOKING NORTH

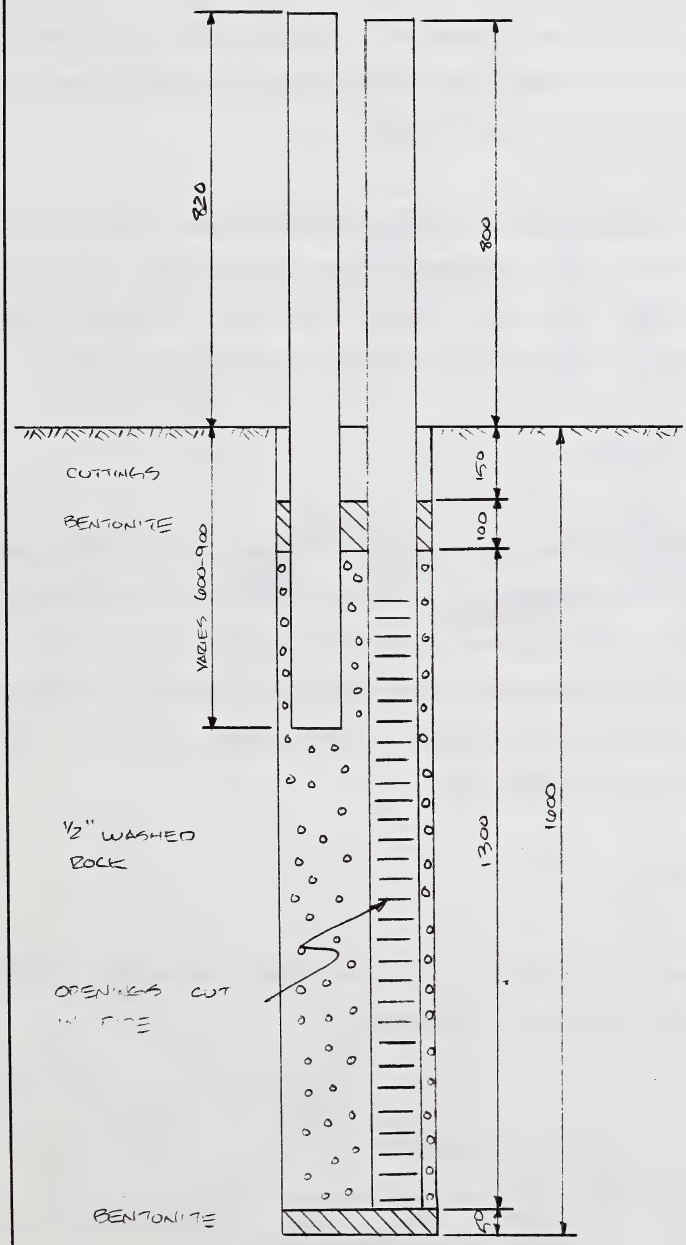

Figure C4

CH2M HILL

3.0 INFILTRATION TEST RESULTS

The purpose of the infiltration study at the research site was to aid in the definition of wet and dry antecedent conditions.

Previous infiltration studies have been conducted on similar soils in the City of Edmonton and the testing has concluded that flooding type infiltrometers provide a representative value of infiltration for modeling purposes.

EBA Consultants Engineering Ltd. conducted constant head laboratory permeability test on two samples and the average permeability was approximately 1.0×10^{-10} m/sec. The onsite infiltration tests were conducted four times throughout the summer to determine relative changes and comparisons to the laboratory values.

3.1 Infiltration Test Procedures

A flooding type infiltrometer was used. Two infiltrometers were installed, one in the native soil (Infiltrometer No. 1) and the other in the backfill zone (Infiltrometer No. 2). PVC pipe was used as the ring for the infiltrometer. The pipe was 250 mm in diameter and approximately 700 mm long. The pipe was jacked into the soil to 500 mm depth by a hoe-tamper. During the testing a constant head was maintained.

3.2 Infiltration Results

Infiltration tests were conducted four times throughout the summer. The results are presented in Figures C5, C6, and C7.

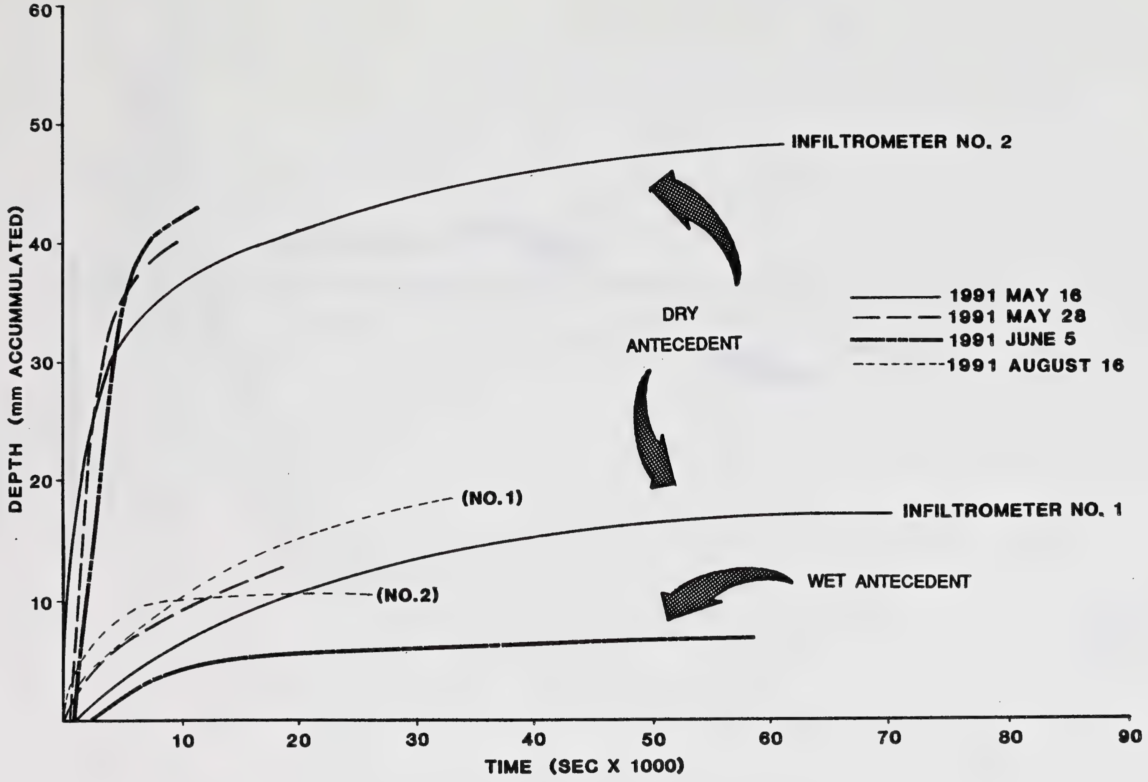

Figure C5 INFILTRATION: ACCUMULATED DEPTH vs. TIME

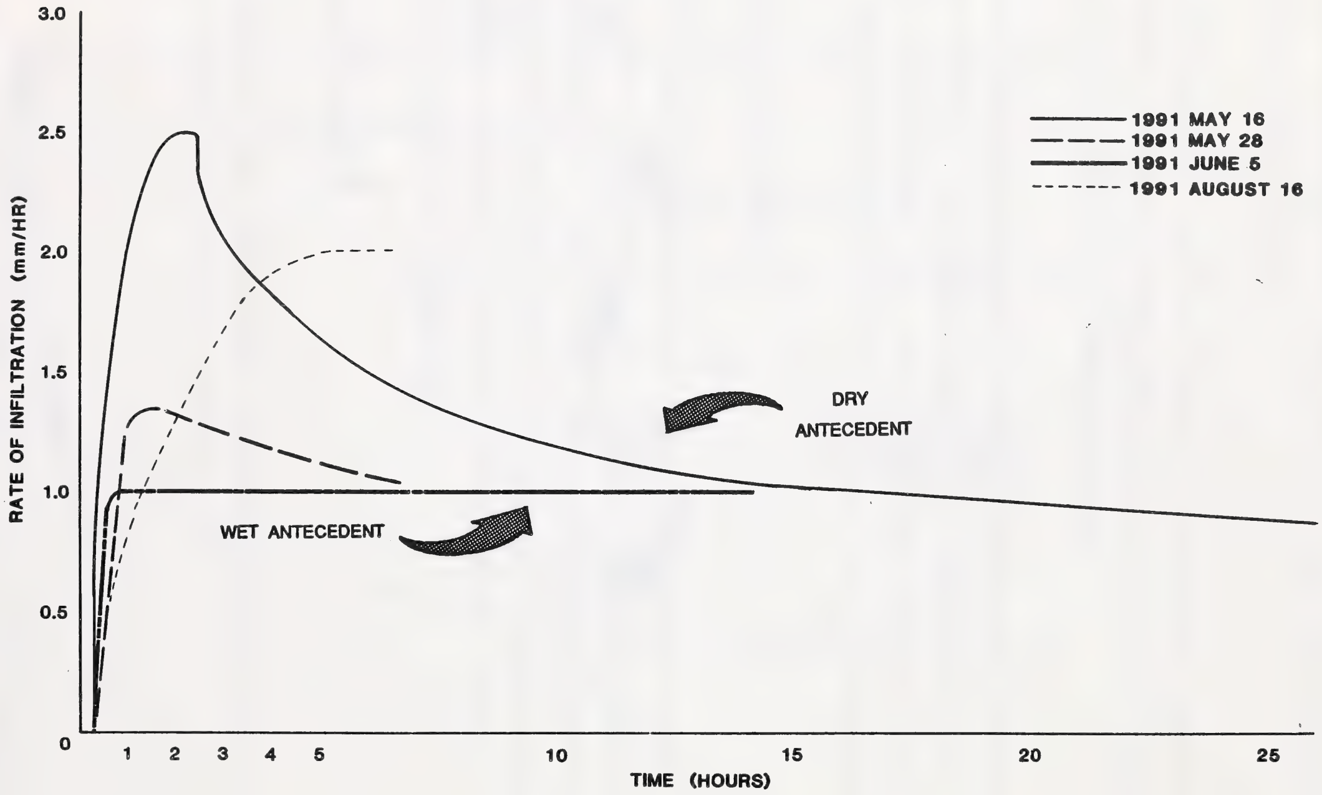

Figure C6 INFILTROMETER NO.1, NATIVE SOIL

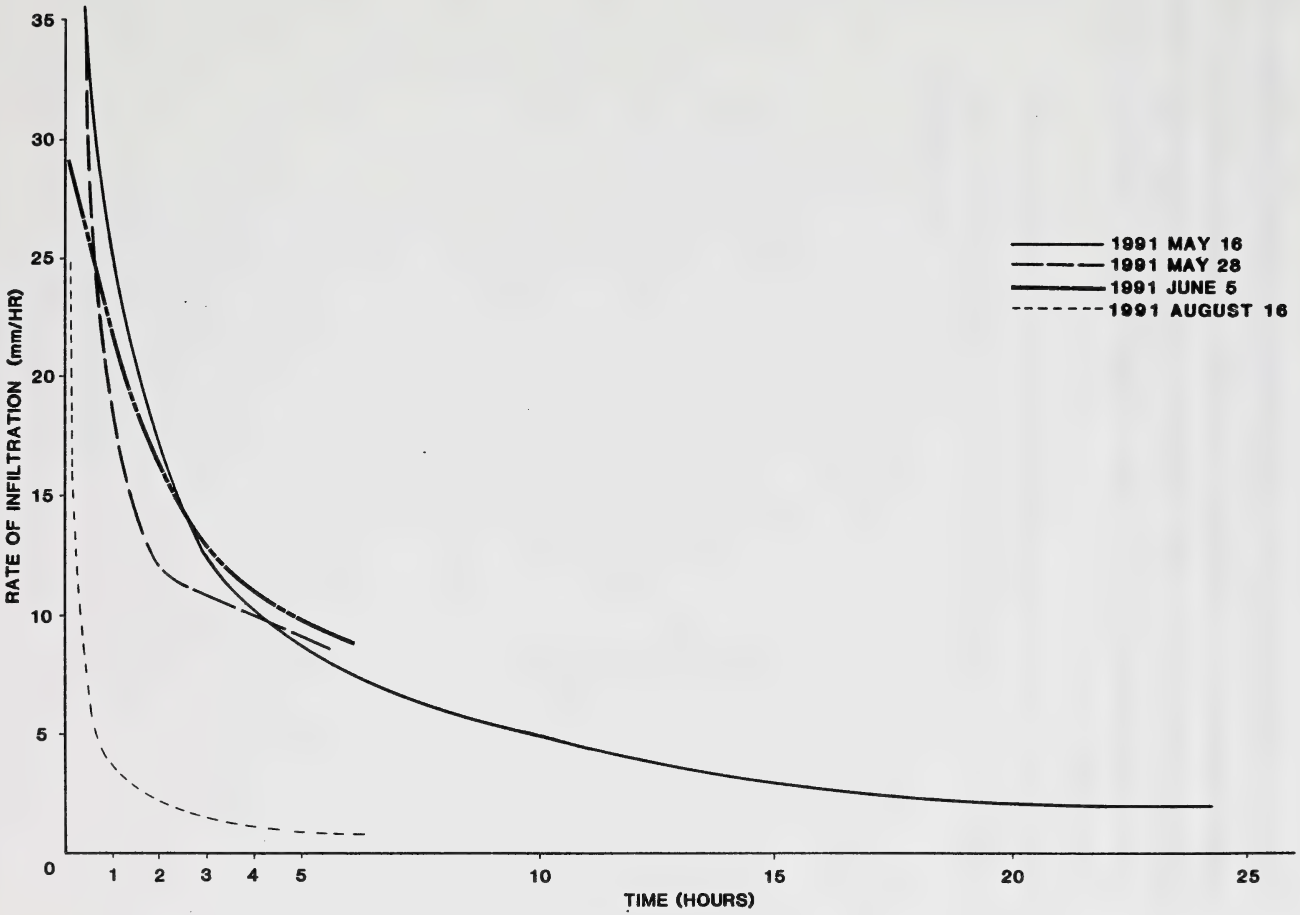

Figure C7 INFILTROMETER NO.2, BACKFILL ZONE

3.3 Observations

The test results show that after initial saturation of the surface the infiltration rate is constant. Dry antecedent conditions (dry surface area) have little effect on infiltration rates after initial wetting. The infiltration rate of native soil is approximately 2.8×10^{-6} m/sec and approximately 1.1×10^{-5} m/sec for the backfill zone.

4.0 DENSITY DETERMINATION, UNIVERSITY OF ALBERTA

Two boreholes were drilled next to the foundation (Figure C8) to a depth of 1.35 m. The field work was carried out to find soil characteristic variations after the application of approximately 920 mm of water (combined natural and simulated rainstorms).

The average soil moisture in the backfill zone was 26.25 percent on the south side of the foundation and 26.45 percent on the north side of the foundation as described in Figure C9.

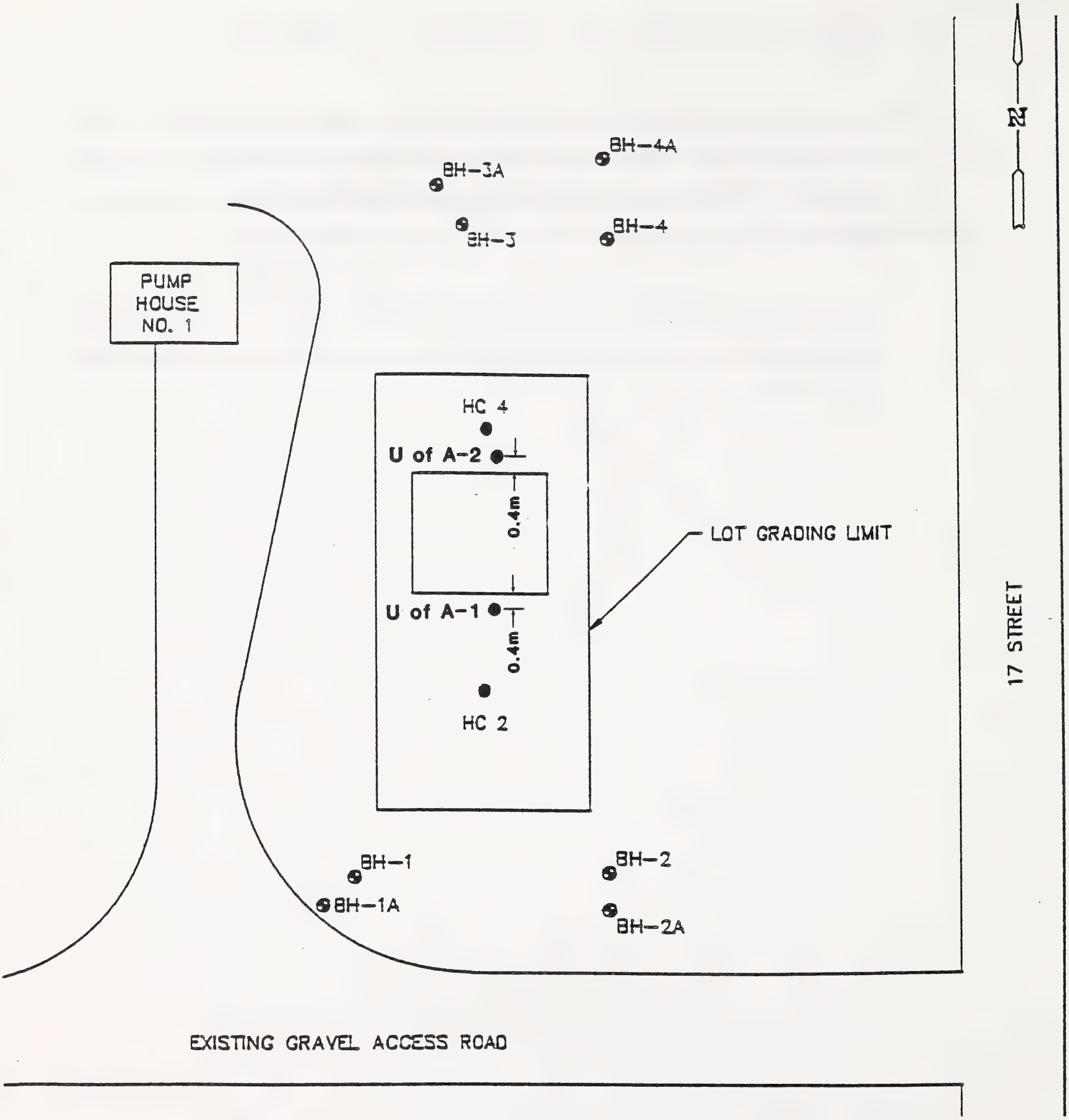

Figure C8 BOREHOLE LOCATIONS

SUMMARY OF UNIT WEIGHT DENSITIES
COUNTY OF STRATHCONA
FOUNDATION DRAIN TEST SITE

1991 June 27

Borehole	Depth (m)	Moisture Content (%)	Wet Density (kg/m^3)	Dry Density (kg/m^3)
1	0.00	26.7	1856	1465
	0.15	27.3	1840	1446
	0.30	28.7	1858	1444
	0.46	25.9	1854	1473
	0.52	25.0	1901	1520
	0.67	25.4	1870	1491
	0.91	25.2	1830	1462
	1.04	26.1	1876	1488
	1.32	25.9	1917	1523
2	0.00	28.9	1844	1430
	0.20	24.5	1956	1571
	0.33	25.2	1941	1551
	0.70	22.0	1994	1635
	0.76	27.3	1873	1472
	0.91	27.6	1834	1438
	1.09	29.4	1865	1442

Figure C9

APPENDIX D

LITERATURE REVIEW

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1.0 REVIEW OF EXISTING PRACTICE FOR FOUNDATION DRAIN DISCHARGE

Municipalities throughout Canada and the U.S. deal with foundation drain discharge by using various methods.

CH2M HILL has reviewed weeping tile connection policies for 19 municipalities in Ontario. Of these, only two, Windsor and North York, allowed discharge to sanitary sewers. St. Catherines requires connection to storm sewers under normal circumstances; but, if this is not feasible, connection to sanitary sewers has been approved. The other 16 municipalities reviewed require connections to storm sewers, sump pumps, or third-line systems.

Some specify that the sump pump should discharge to the storm sewer. Winnipeg requires sump pits with sump pumps in all buildings with basements installed since 1987. Foundation drain flows are to discharge to grade.

In Chicago, foundation drains are required to be connected to sump pumps with discharge to storm sewer systems or drainage ditches.

The Ontario Ministry of the Environment and Ontario Municipal Engineers Association standards say that the connection of foundation drains to sanitary sewers is discouraged or not recommended.

In the City of Edmonton, the requirements for foundation drain discharge have changed over time. In the City's design guidelines for 1972, 1974, 1976, and 1982, foundation drains were to be connected to the sanitary sewer system. In the 1986 guidelines, weeping tile discharge locations are listed as sanitary sewers, storm sewers, or ground level via sump pump. The 1988 standard disallows foundation drains discharge to sanitary sewers.

1.1 Alberta Building Code Requirements for Foundation Drains

Requirements for foundation drainage according to the Alberta Building Code are summarized as follows:

- Exterior footing drainage is to be provided via drainage tile or pipe laid around the exterior of the foundation, or a layer of crushed rock or gravel.
- Specifications to which various allowable materials must conform are listed.
- The minimum diameter of a foundation drain pipe is 100 mm.
- Foundation drain pipe is to be laid so that the top of the drain pipe is below the bottom of the floor slab.
- Coarse, clean granular cover 150 mm deep is to be provided on the top and on sides of the foundation drain pipe.
- If granular material alone is to be used, it must extend at least 125 mm below the building and 300 mm from the outside edge of the footings.
- The foundation drain shall discharge to a building drain, storm drain, drainage ditch, dry well, or ground surface.
- If sumps are provided, the minimum dimensions are 750 mm deep with surface area of 0.25 m^2. An automatic sump pump is required where gravity drainage is not feasible.

1.2 Review of Previous Tests

Where foundation drains are connected to the sanitary collection system, the quantification of resulting flows has been frequently investigated and, in several instances, field tests carried out. Studies carried out by various municipal and provincial organizations in three areas to investigate the topic are reviewed and summarized below.

1.2.1 Winnipeg

Studies carried out in Winnipeg (1,2) were directed at determining the magnitude of flows, the relationship between weeping tile flows and rainfall, the effects of on-lot practices, and the contribution from roof leader flows. Seven lots were observed.

The program was intended to focus on natural rainfall events. But, the rainfall for the year (1972) was lower than normal and additional testing involving roof leader flows was carried out. Uniform rates of flow were applied to roofs and the results recorded. The rates and discharge locations were varied.

The on-lot apparatus consisted of a pump with an electronic strip chart recorder. A network of seven municipally operated raingauges were used to measure rainfall at the particular sites. Each test site had one raingauge in its area.

The data recorded were analyzed; the following is a summary of test results:

- Time lapse from start of rainfall to start of drain flow varies from zero to more than one hour.
- Peak flows varied from a trickle to 0.45 L/s.
- Lag time is a characteristic of each individual lot but is also very dependent on antecedent condition.
- Results suggest that lot grading conditions next to the homes have a significant impact on foundation drain flows.
- The roof flow simulations led to the conclusion that the roof flows generate the majority of foundation drain flows

(60 percent). Thirty percent of the rainfall that falls on the house and the dished area around the house, typically resulting from settled backfill material, enters the weeping tile.

- This study did not address soil characteristics nor did it consider a model for correlation of predicted flows to actual flows.
- Roof contributions to foundation drain flows were very high. Over a longer period, say 24 hours, as much as 50 percent of the total roof volumes is estimated to enter the foundation drains. In addition, it was estimated that 10 percent of the total runoff from entire areas is conveyed to sanitary sewers.
- Homes with proper lot drainage had only 25 percent of the flowrate of a house with poor lot grading.

1.2.2 Ontario

Studies were carried out by the Ontario Ministry of the Environment to assess the quantity and quality of foundation drain water (3). Information was gathered on foundation drain weeping tile flows due to several parameters, including:

- Soil type
- Backfill slope
- Weeping tile
- Roof drainage

The study consisted of five residences in Ontario, each equipped with a tipping bucket raingauge on the roof and a pump recorder on a sump pump. Two additional locations, where the apparatus was initially tested, were also analyzed. Technical problems were encountered and as a result not all records are complete. In addition to rainfall-related flows in foundation drains, the effects of snowmelt were examined.

The study notes the following:

- In response to rainfall, a maximum hourly drain flow of 1960 L was measured.
- In response to rainfall and snowmelt, a daily maximum flow of 13 600 L was measured.
- Direct relationships between rainfall and foundation flows could not be established.
- The extreme case noted will result in foundation drain flows accounting for 20 percent of yearly sanitary flows in situations where the foundation drain is connected to sanitary sewers. General cases suggest 6 to 10 percent. Even the general case figures have an impact on conveyance and treatment costs.

1.2.3 Milwaukee

As part of an inflow/infiltration (I/I) study, the Milwaukee Metropolitan Sewerage Division (MMSD) carried out an analysis of extraneous flows into sanitary sewers (4).

The on-lot portion of the study used a group of homes along a two-block stretch, as well as homes scattered throughout the rest of the city. Participation by home owners was voluntary. Each home studied had metering equipment installed to monitor:

- Water consumption
- Flowrates in sewer service connections
- Flowrates from sump pumps connected to foundation drains.

If the home selected lacked a sump pump, one was installed at no cost to the home owner. Sewer service lateral line repairs, if required, were also carried out at no cost.

Field testing consisted of:

- Rainfall simulations
- Smoke and dye testing of sewer service lines to check for leakage
- Foundation drain flooding using hoses at ground level

The maximum measured flowrates for various time periods showed large variations. The average rates for 31 sites were:

1 hour	0.10 L/s	(1.6 USgpm)
1 day	0.012 L/s	(280 USgpd)
2 days	0.009 L/s	(210 USgpd)
3 days	0.007 L/s	(150 USgpd)
7 days	0.004 L/s	(100 USgpd)

The maximum recorded 1-day flowrate was 0.064 L/s (1,460 USgpd). The MMSD study notes the following points:

- The average maximum hourly I/I from sump pumps and foundation drains connected to sanitary sewers was 0.189 L/s

(3 USgpm).

- I/I rates observed from sump pumps and foundation drains varied significantly, but homes in clayey type soil and those with positive drainage or in elevated and terraced lots experienced lower I/I rates.

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